Global Change Information Resources

Second edition
September 1992

GLOBAL CHANGE INFORMATION PACKET: GLOBAL CLIMATE CHANGE

Recent scientific observations have led to concern that human activities could be adversely affecting the Earth's climate. In particular, much attention has been focused on global warming or an accelerated "greenhouse effect" which suggests that more of the Earth's heat will be retained in the atmosphere by increasing amounts of heat-absorbing trace gases such as carbon dioxide, chlorofluorocarbons (CFCs) and methane produced as a result of human activities. Scientists believe that if such a warming of the Earth's climate were to occur, it would have serious consequences for human activities, including agriculture and forestry.

The National Agricultural Library (NAL) has prepared this Global Change Information Packet on global climate change to provide information for the general public. It describes the concerns surrounding and potential effects of global climate change, lists books and journal articles which discuss these concerns more fully, and describes how to obtain additional information.

NAL is part of the U.S. Department of Agriculture. It is the largest agricultural library in the world, containing over 2.1 million volumes and receiving 26,000 current periodical titles from throughout the world. Along with the Library of Congress and the National Library of Medicine, NAL is one of three national libraries of the United States.

The materials listed in this Information Packet are available through your local library. The librarian in your public, state, university, or corporate library can assist you in obtaining materials either in your area or directly from the NAL.

For additional information on global climate change contact:

D.C. Reference Center of the NAL
Room 1052 South, U.S. Department of Agriculture
14th & Independence Ave., SW, Washington, DC 20250
Telephone (202) 720-3434

For additional copies of this free Information Packet, send your request (and a mailing label) to:

Reference Section, Room 111
National Agricultural Library
10301 Baltimore Blvd.
Beltsville, MD 20705

National Agricultural Library

U.S. Department of Agriculture

Beltsville, MD 20705

Editors:
Janet Wright and Douglas E. Jones

CONTENTS

ACKNOWLEDGMENTS

The National Agricultural Library wishes to thank the following for permission to reprint articles: Sigma Xi, the Scientific Research Society; Jane S. Brookes; Marine Technology Society; and the U.S. Environmental Protection Agency.

DISCLAIMER

July 1992

Global Change Information Resources

Second edition
September 1992

National Agricultural Library

U.S. Department of Agriculture

Beltsville, MD 20705

GLOBAL CLIMATE CHANGE AND AGRICULTURE A SUMMARY

by Susan C. Whitmore
Bureau of Mines
U.S. Department of the Interior

The atmospheric accumulation of carbon dioxide (CO_2) and other gases from burning fossil fuels and other human activities may be enhancing the atmosphere's capacity to trap infrared radiation emitted by the Earth. The trapping of radiation warms the Earth's surface in a process similar to that which occurs in a greenhouse, hence the often used term "greenhouse effect." If increased warming were to occur, climate changes could cause serious consequences for human activities and resources in areas such as energy production and use, climatic patterns, coastal land use, agriculture, forestry, and water supplies, and also could produce population shifts. Although causal relationships between long-term climate changes and recent weather trends have not yet been established, such conditions have focused public attention on potential climate changes and the need for better understanding of climate.

WHAT IS THE "GREENHOUSE EFFECT"?

A blanket of air envelopes the Earth and moderates the Earth's temperature. This blanket is made up of abundant or major gases, such as nitrogen and oxygen, and minor gases, such as water vapor and carbon dioxide. The atmosphere controls the Earth's temperature because some of the minor atmospheric gases, including those of natural origin and some produced by human activities, are relatively transparent to incoming short-wavelength sunlight, but are opaque to longer wavelength infrared radiation arising from the Earth's surface and from the lower atmosphere. This mechanism of control has been termed the "greenhouse effect," since it is similar to the processes which occur in a greenhouse where the glass envelope acts like a compressed atmosphere, passing and absorbing radiation of different wavelengths, with the temperature inside the greenhouse rising to a level above that of the surroundings.

On Earth, sunlight not reflected by clouds or absorbed by the atmosphere is either absorbed by the Earth's surface or reflected back to space. The absorbed energy warms the surface of the Earth, which acts as a radiator, re-emitting energy upward into the atmosphere.

The energy that is absorbed and re-radiated at the surface of the Earth and at the various levels in the atmosphere maintains the Earth at a life-sustaining temperature that is warmer than it would be if there were no intervening atmosphere. Without atmospheric "greenhouse gases" and the resulting

"greenhouse effect" the Earth's average surface temperature might be as low as -20 degrees Celsius (C) (-4 degrees Fahrenheit (F)).[6]

Natural processes contribute "greenhouse gases" to the atmosphere. However, many people are concerned that human activities are increasing the atmospheric concentrations of carbon dioxide (CO_2) and other "greenhouse gases" which, given no other mitigating effects, will lead to more efficient absorption of energy by the atmosphere, producing global warming and its accompanying effects.

A seemingly small change in overall atmospheric temperature can have a large effect on the Earth. The Earth has not been more than 1 to 2 degrees C (1.8 to 3.6 degrees F) warmer during the 10,000-year era of human civilization. The previous ice age, in which glaciers stretched from present day New York to Chicago, was only 5 degrees C (9 degrees F) cooler than now.[6]

WHAT ARE "GREENHOUSE GASES"?

The four most important "greenhouse gases," whose atmospheric concentrations can be influenced by human activities, are carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons.

- Carbon dioxide (CO_2) occurs naturally in the atmosphere, and plays an important role in almost living organisms. Animals, including humans, exhale it while plants take it in, using the carbon it contains to manufacture carbohydrates. There has been a 25-percent increase in CO_2 in the last 100 years.[6] The burning of fossil fuels (coal and oil) and deforestation are the primary contributors of CO_2 from human activity.

- Methane is the major constituent of natural gas and is also produced from many biological decay processes (in the digestive system of ruminant animals such as cattle or deer, and in rice fields and wetlands). Rice production is believed to be the primary contributor of methane from human activity.[8] There has been a 100-percent increase in methane in the past 100 years.[6]

- Nitrous oxide (laughing gas) is produced from microbial action in the soil. Of the nitrous oxide released each year, about 10 percent is due to the use of fertilizer.[9] Natural microbial activity; the spread of agriculture; and the burning of forest vegetation, crop residues, and fossil fuels account for most of the rest.

- Chlorofluorocarbons (CFCs) are used as the cooling fluids in refrigeration, as propellants in aerosols, as solvents, and as foam-blowing agents in the production of plastics. Unlike the other greenhouse gases, CFCs are not produced naturally and their presence in the atmosphere is due solely to industrial production. Virtually all CFCs produced eventually end up in the atmosphere and are very long-lived.[9]

IS THE EARTH WARMING?

Whether global warming due to an accelerated "greenhouse effect" is actually occurring is controversial.

- James E. Hansen, Directory of the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies, New York City, and his colleagues analyzed temperature records dating from 1880 to 1985. Their results indicate a global warming of 0.5 to 0.7 degrees C (0.9 to 1.26 degrees F) in the past century.[1]

- Thomas M.L. Wigley and his colleagues, from the University of East Anglia in England, also have shown an increase in average global temperature.[3]

- Climatologists Thomas Karl, Kirby Hanson, and George Maul at the National Oceanic and Atmospheric Administration (NOAA) completed a study that shows no overall increase in annual temperature for the contiguous U.S. from 1895 to 1987.[2]

- An exhaustive study of worldwide ocean temperatures since 1850 by MIT climatologists Reginald Newell and his colleagues concludes that, "There appears to have been little or no global warming over the past century."[5]

- The U.S. National Academy of Sciences concludes that, based on model predictions, a 1.5 to 4.5 degrees C (2.7 to 8.1 degrees F) global warming may occur in the next century.[6]

- The seven warmest years recorded in the past 100 years (based on average global temperatures) were 1990, 1988, 1987, 1983, 1981, 1980, and 1986, in that order.

POTENTIAL EFFECTS OF GLOBAL CLIMATE CHANGE

Estimates of global warming by the middle of the 21st century vary from 2 to 9 degrees C (3.6 to 16.2 degrees F).[4] If a significant temperature rise were to occur, important changes might be seen on the Earth's surface. Global warming could affect energy production and use, climatic patterns, agriculture, forestry, and water resources. It could lead to rising sea levels and the flooding of coastal regions.

While a direct relationship between long-term trends and recent warm weather has not been established, such conditions have focused public attention on potential climate change and its resulting effects.

The Environmental Protection Agency drafted a report entitled *The Potential Effects of Global Climate Change on the United States* in which they speculated about the following possible effects of climate change on agriculture and forestry.[7]

Potential Effects of Global Climate Change on Agriculture

Agriculture is a critical U.S. industry, providing food for the Nation's population and as much as $43.6 billion in exports for the Nation's trade balance. In 1985 total farm assets were $771 billion, and food and fiber crops represented 17.5 percent of the total gross national product.[7] Wheat, corn, soybeans, cotton, fruits and vegetables, and livestock are among the most important U.S. agricultural commodities.

Although climate change is not likely to threaten U.S. food supplies, it may:

- Reduce or increase average yields of corn, soybeans, and wheat, both rainfed and irrigated. Increased yields may occur in northern latitudes where warmer conditions would provide a longer frost-free growing season. Decreased yields may occur in mid-latitudes primarily from higher temperatures which shorten a crop's life cycle.

- Increase the yields of corn, soybean, and wheat since increased atmospheric CO_2 may increase plant growth.

- Result in a northward shift in cultivated land, causing significant regional dislocations in agriculture with associated impacts on regional economies.

- Shift rainfall patterns, which might expand crop irrigation requirements in certain regions and, hence, increase competition for regional water supplies and increase surface and ground water pollution.

- Change the ranges and populations of agricultural pests. These effects could change pest control requirements.

- Result in sea level rise and the flooding of near-coastal agricultural lands.

Potential Effects of Global Climate Change on Forestry

Forests occupy 33 percent of the U.S. land area and exist in all 50 states. In total, they occupy 738 million acres and are rich in resources such as water and wildlife. Global warming could affect the forests of the U.S. significantly. Changes could be apparent in 30 to 80 years, depending on the region, a site's quality, and the rate of climate change.

- The southern ranges of many forest species in the eastern United States could experience dieback of several hundred miles depending on the extent of temperature changes and drying soils. This dieback could result in a serious loss of productivity, depending on how dry the soils become.

- The potential northern range of forest species in the eastern United States could shift northward as much as 400 miles over the next century. Productivity could increase along the norther limits of some eastern species.

- If elevated CO_2 concentrations substantially increase tree growth through an increase in photosynthesis and efficiency of water use, the southern declines could be alleviated.

- If climate stabilizes, forests might eventually regain a generally healthy status over a period of several centuries. In the meantime, declining forests could be subject to increased fires, pest attacks, disease outbreaks, wind damage, and air pollution.

- Additional possible impacts of changes in forests include reductions in biotic diversity, increased soil runoff and erosion, reduced aquifer recharge, and changes in wildlife habitat and recreation.

Many of these speculations about the possible effects of global climate change are controversial. For instance, the influence of an accelerated global climate change on rainfall patterns is uncertain. Some global models predict reduced rainfall, other increased rainfall, and still other only a change in the pattern of rainfall.

Because of the global implications of this problem, scientists, diplomats, and policymakers are combining efforts to achieve consensus on an eventual agreement concerning global warming.

A major component of international cooperation is the Intergovernmental Panel on Climate Change (IPCC) which was set up in 1987 by the World Meteorological Organization (WMO) and the United Nations Environmental Programme (UNEP) to asses the scientific information "related to the various components of the climate change issue" and formulate "response strategies for the management of the climate change issues" (see *Chronology of Global Climate Change*).

WHAT CAN YOU DO?

- Become knowledgeable about the issues involved in global climate change. The bibliographies and the directory of organizations included in this Global Change Packet will lead you to additional information. Specifically, the pathfinder lists publications that discuss global climate change and agriculture.

- If you are concerned about how to counteract human activities which contribute to production of "greenhouse gases," specific suggestions are given in:

  Bates, Albert K. *Climate in Crisis: The Greenhouse and What You Can Do About It.* Summertown, TN: Book Pub. Co., 1989. 304 p.

  Earth Works Group. *50 Simple Things You Can Do to Save the Earth.* Berkeley, CA:

Earth Works Press, 1989. 96 p.

Hollender, Jeffrey. *How to Make the World a Better Place: A Guide to Doing Good.* NY: William Morrow, 1990. 303 p.

MacEachern, Diane. *Save Our Planet: 750 Everyday Ways You Can Help Clean Up the Earth.* Washington, DC: National Wildlife Federation, 1990. 210 p.

LITERATURE CITED

1. Hansen, James and Sergej Lebedeff. Global Trends of Measured Surface Air Temperature. *Journal of Geophysical Research*, p. 13, 345-13, 372, November 20, 1987.

2. Hanson, K., G.A. Maul, and T.R. Karl. Are Atmospheric Greenhouse Effects Apparent in the Climatic Records of the Contiguous United States (1895-1987)? *Geophysical Research Letters*, p. 49-52, January 1989.

3. Jones, P.O., T.M.L. Wigley, and P.B. Wright. Global Temperature Variations Between 1861 and 1984. *Nature*, p. 430-434, July 1986.

4. Morrison, Robert E. *Global Climate Change* (CRS Issue Brief: Major Tracking Issue). Washington, D.C.: The Library of Congress, Congressional Research Service, January 5, 1990. 20 p. (available to members of Congress only)

5. Newell, Reginald. Earth's Climatic History. *Technology Review*, p. 30-45, December 1974.

6. Schneider, Stephen H. Cooling It. *World Monitor*, p. 30-38, July 1990.

7. Smith, Joel B. and Dennis A. Tirpak. *The Potential Effects of Global Climate Change on the United States: Draft Report to Congress.* Washington, DC: Environmental Protection Agency, Office of Policy, Planning, and Evaluation, Office of Research and Development, October 1988.

8. Strommen, Norton D. *A Global Perspective on Weather Trends - The Most Unpredictable & Least Controllable Nature Resource.* Paper presented at the World Food Production Symposium, November 6, 1989, in Rio de Janeiro, Brazil.

9. United National Environment Programme. *The Greenhouse Gases.* Nairobi Kenya: UNEP, 1987. 40 p.

Global Change Information Resources

Second edition
September 1992

National Agricultural Library

U.S. Department of Agriculture

Beltsville, MD 20705

CHRONOLOGY OF GLOBAL CLIMATE CHANGE

by Jayne T. MacLean
Alternative Farming Systems Information Center
National Agricultural Library

It is well known and accepted, at both the scientific and the popular level, that global-scale climate changes occur very gradually over long periods of time. Scientists have documented the gradual fluctuations by identifying changes in soil layers and rocks, and bubbles trapped in glacial ice.

However, there is increasing evidence that human activities may be accelerating this natural phenomenon. Over the years, humans have changed rivers, seas, forests, and soils; expanded the amount of land covered by cities, highways and farms; and increased the amount of gases discharged into the atmosphere.

Some recent studies reveal a slow rise in the average earthly temperature over the last 100 years. Now, scientists are challenged to determine whether this climate channge is actually occurring, how much of this change is occurring naturally, and to what extent human activities are contributing to and accelerating the changes.

The following provides a historical perspective of events leading to the world's current awareness of global climate change.

Early 1800's	The Industrial revolution begins in Great Britain, spreading around the developed world. Fossil fuels like peat, coal and, later, oil used to power industry.
1863	John Tyndall, British scientist, describes how water vapor in the atmosphere helps to keep the world warm.
1896	Svante Arrhenius, a Swedish chemist, warns that carbon dioxide (CO_2) released to the atmosphere from burning coal for industrial power is likely to make the world warmer.

1930	An American engineer, Thomas Midgley, proposes using new chlorofluorocarbons (CFCs) instead of poisonous ammonia for cooling refrigerators.
1957	International Geophysical Year. Regular monitoring of atmospheric CO_2 begins in Hawaii and Antarctica.
1970's	Climatologists with high-speed computers begin projecting warming of 3 to 9 degrees by the end of the 21st century, based on carbon dioxide emissions.
1985	At an October meeting, scientists from 19 countries agree with a study crediting other trace gases, including CFCs, with adding as much to the greenhouse effect as CO_2.
1987	Global Climate Protection Act, P.L. 100-204, becomes law. Montreal Convention is held to consider how to limit atmospheric pollution by CFCs.
1987	Our Common Future, known as the Brundtland Report after its chairman, Gro Harlem Brundtland, publishes the findings of the World Commission on Environment and Development. While its conclusions do not please all environmental experts, it is a major information resource and rallying point.
1987-1988	Drought, fires, and severe heat waves arouse public anxiety and conjecture that they are first signs of global warming.
1988	Intergovernmental Program on Climate Change (IPCC) is convened in Geneva for the first time.
1989	Seventy-one nations, meeting in The Netherlands, agree to a Declaration on Atmospheric Pollution and Climatic Change.
1990	At the fourth meeting of the IPCC in Sweden, the United States join 73 other nations in agreeing that humans' activities are causing the Earth's atmosphere to heat up.
1991	President Bush hosts a climate change treaty negotiating session in Chantilly, VA, in February.
1991	United Nations environment conferences are held in Nairobi, Kenya in June and in Geneva, Switzerland in September.
1992	In June, the world focuses its attention on the "Earth Summit," the United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil. Treaties and agreements which are negotiated, and signed by leaders of many countries, may lead to more sensitive use of the planet's diminishing resources.

Global Change Information Resources

Second edition
September 1992

National Agricultural Library

U.S. Department of Agriculture

Beltsville, MD 20705

GLOBAL CLIMATE CHANGE
SELECTED ANNOTATED BIBLIOGRAPHY

by Douglas E. Jones
Science-Engineering Library
The University of Arizona
Tucson, Arizona

The following articles have been carefully selected to expand the breadth and depth of information presented elsewhere in the Global Change Information Packet. Most articles have been chosen from journals likely to be available in most medium-sized public or college libraries.

Abelson, Philip H. Uncertainties about Global Warming. *Science*, p. 1529, March 30, 1990.

Abelson critically examines the quality and reliability of key evidence relating to global warming. He finds that "[i]f the situation is analyzed applying the customary standards of scientific inquiry one must conclude that there has been more hype than solid facts." The estimates of the 14 or so groups attempting to model global climate show a range of 1.5 to 5.0 degrees Celsius (C). Most agree that the models are deficient. For example, the models do not adequately account for the effects of clouds which "have both negative and positive effects on warming." He goes on to note that while many researchers cite a 0.5° C. increase in temperature since 1880, the change really depends on the time interval chosen. Temperature increased from 1880-1940, but then dropped from 1940 until the 1960's to the extent that a new ice age was predicted. A recent study looking at the 1979-1988 period using precise satellite data showed no obvious trend. Abelson concludes, however, by stating that despite the uncertainties and even if there were a "negligible greenhouse effect, we should be taking actions" such as inducing conservation and energy efficiency by raising taxes on fuels, and expanding efforts to develop renewable resources. Whatever is done "should be based on well-thought-out long-range goals."

Barnwell, George. Your Contribution to Global Warming. *National Wildlife*, p. 53, February-March 1990.

Barnwell examines the relationship between electric energy used in the home and the carbon dioxide (CO_2) produced by a coal-fired electric generating plant. For example, a 100-watt bulb used as a night light 365 days a year would result in 675 pounds of carbon dioxide being released into the atmosphere as a result of coal burned to produce the necessary electricity. A brief table gives similar information for a variety of common household appliances.

Beardsley, Tim. Not So Hot: New Studies Question Estimates of Global Warming. *Scientific American*, p. 17-18, November 1989.

Predictions about global climate - whether warming or cooling - are based on two fundamental components. First is the recognition and understanding of the complex interactions which create climate, the scientific basis. Second are the models which attempt to manipulate that information in a realistic way to make predictions. Beardsley examines many of the current weaknesses in both components. For example, it's not clear what role clouds play since they both absorb heat from the earth and reflect heat from the sun. Recent studies show that ice clouds may have a much greater reflectance than water clouds. In another piece of related research "data suggest that sulfate aerosols formed from pollutants... can significantly increase the earth's albedo." Ocean circulation and heat exchange is also a complex process which has not been adequately accounted for in many models. Other factors such as fluctuations in the brightness of the sun may also play a role. More research and the development of more sophisticated models are necessary to provide better answers.

Crosson, Pierre. Greenhouse Warming and Climate Change - Why Should We Care? *Food Policy*, p. 107-118, May 1989.

Crosson provides a careful and well-documented review of greenhouse warming and its likely effects on climate. Special attention is given to the impact on agriculture and the overall economic and environmental costs of world agricultural production. The scientific conclusion is that less than half the current annual carbon emissions are captured by the oceans and terrestrial sinks, and the increasing concentrations of greenhouse gases will certainly affect climate, although the full effect may not be evident for several decades. The social conclusion is that we must care enough to take action now for three reasons. "First, the potential threats of climate change to human welfare are at least as severe as many of those we now take seriously. Second, the moral imperative of intergenerational equity imposes on out generation the obligation to consider seriously the consequences of our actions on the welfare of future generations. Third, by beginning to mobilize now to reduce greenhouse gas emissions...we have a chance...to hold future climate change within limits..."

Evans, Gary R. Agriculture, Forestry, and Food Security in Relation to Global Change. *Marine Technology Society (MTS) Journal*, p. 30-37, v.25, no.4, Winter 1991-1992.

Evans, Special Assistant for Global Change Issues in the U.S. Department of Agriculture, asserts that the greatest threat posed by global change is from the potential effects on our ability to produce food and fiber. Acknowledging that more research needs to be done, he proposes a comprehensive approach which would permit maximum flexibility in selecting responses while achieving global results. He proposes two general types of strategies: Mitigating strategies could be used to limit or offset emissions of greenhouse gases such as promoting no-tillage farming and reduction in the burning of trees and other forms of biomass. Adaptation strategies facilitate natural and societal adjustment to the effects of global change such as genetic improvement, bioengineering stress tolerance, or altering agricultural management systems.

Fulkerson, William, *et al.* Global Warming: An Energy Technology R & D Challenge. *Science*, p. 868-869, November 17, 1989.

Fulkerson asserts that there are two major uncertainties with regard to "future energy technology needs: (i) growth of energy demand and (ii) the seriousness and urgency of the greenhouse effect." To accommodate these uncertainties he proposes a broad-based research and development (R & D) effort which addresses both improving energy sources and improving the efficiency of energy use. The major non-fossil fuel technologies are evaluated with respect to performance, cost, and social acceptance plus an estimate of how much R & D funding would be required to make them competitive. The proposed increased spending on energy R & D is likened to an insurance policy in which the risk is small and the likelihood for success large.

Gribbin, John and Mary Gribbin. Climate and History: the Westvikings'Saga. *New Scientist*, p. 52-5, January 20, 1990.

This interesting article shows how warming and cooling trends of only 1-2 degrees over the last 1200 years have affected the settlement patterns of Iceland and Greenland by Europeans. The Greenland colonies, for example, survived for approximately 500 years from 1000 to 1500 A.D. but were ultimately "frozen out" because of increasing cold and their failure to modify their traditional European clothing and agricultural practices.

de Groot, Peter. Are We Missing the Grass For the Trees? *New Scientist*, p. 29-30, January 6, 1990.

Much attention has been focused on the role of forests and plankton in the global carbon budget; de Groot reviews new findings from a study by the United Nations Environment Programme (UNEP) which shows that grasslands convert more carbon dioxide into carbohydrates than was previously believed, perhaps equalling - or exceeding - the productivity of tropical rainforests. Previous estimates apparently did not take into account roots or the differences in growth patterns between temperate and tropical grasses. They also found that "when grasslands are cleared for agriculture, the new crops are likely to be less productive than the original species of wild grasses." In a related finding, de Groot notes that 700 million hectares of savanna are burned each year, often to kill pests and encourage new growth. Paul Crutzen of the Max Planck Institute for Chemistry has calculated that the savanna burning may contribute "three times as much carbon dioxide to the atmosphere as burning the rainforests."

Hammond, Allen L., Eric Rodenburg, and William R. Moomaw. Calculating National Accountability for Climate Change. *Environment*, p. 11-15, 33-35, v.33, no.1, January/February 1991.

As one component of an international agreement aimed at limiting man-caused emissions of greenhouse gases, the authors propose a Greenhouse Index based on each country's "greenhouse forcing contribution." This index could then be used as "a measure of national accountability for contribution to the greenhouse effect" and could guide international and national decisionmaking. For example, using 1988 data, their analysis showed that the largest contributors to greenhouse forcing were the United States (17.1%), USSR (13.5%), China (8.1%), and Brazil (5.7%). In assigning responsibility, the authors hope the index will "promote discussion, argument, and action."

Matthews, Samuel W. Under the Sun - Is Our World Warming? *National Geographic*, v.178, no4, October 1990, p. 66-99.

In this heavily illustrated article Matthews focuses on the effects of man's activities and the sun's radiant energy on Earth's atmosphere. Data collected and projections made by scientists at agencies such as NOAA, NASA, and the National Center for Atmospheric Research are presented. The data indicate that temperatures worldwide have increased approximately one degree Fahrenheit since the late 1800s. Matthews predicts a warming of three to nine degrees by the middle of the next century, if atmospheric carbon dioxide doubles as many predict. He also touches on other variables affecting climate such as the influence of the oceans, the cooling effect of clouds, volcanic eruptions, and fluctuations in the sun's output as well as other "greenhouse gases." He concludes that human activities are probably affecting our climate and includes suggestions from several scientists as to actions that should be taken now.

McInerney, Susan. ReLeafing the World. *Country Journal*, p. 22-3, January/February 1990.

The author provides an overview of the "Global ReLeaf" project sponsored by the American Forestry Association, a Washington, D.C.-based conservation organization. In addition to directly reducing atmospheric carbon dioxide, trees can be used to conserve energy and reduce fossil fuel consumption. For example, "[t]hree trees properly planted around the home can produce enough shade to cut air conditioning costs by 10 to 15 percent. Those planted as windbreaks can reduce heating costs considerably."

Night Heat: Sulfate Pollutants May Slow Daytime Warming. *Scientific American*, February 1992, p. 21,24.

The results of a new study by Thomas R. Karl of the National Climatic Data Center suggest that most of the temperature increase recorded in the last century, at least in the Northern Hemisphere, is the result of higher daily minimum temperatures which means the nights are getting warmer. Daily maximum temperatures usually recorded during the daytime have hardly increased at all. One possible explanation is that tiny sulfate articles from the burning of fossil fuels reflect sunlight during the daytime. At night, with no sunlight to scatter, the atmosphere absorbs the heat radiated by the earth, thus concentrating the increase in nighttime temperatures. Sulfate aerosols may also play a role in cloud seeding but it is not yet clear what role increasing cloudiness may have on global warming.

The Once and Future Weather. *Economist*, p. 95-100, April 7, 1990.

Provides a careful and readable review of climate history over approximately the past 100,000 years, including the various chemical, tree-ring, and fossil records. Irregularities in the earth's shift ("wobble") on its axis of rotation and variation in the shape of its orbit around the sun produce the Milankovitch cycles which have a profound, and apparently predictable, effect on climate. Apparent changes in the circulation patterns of the oceans, which move shallow waters to deep ocean depths, significantly affect the CO_2 absorbing activities of the oceans and, therefore, climate. Given these large, epochal changes, it is not clear what effect, if any, the current increase in atmospheric CO_2 will have on global climate.

Page, Jake. A Question of Degree: Parks Forecast the Effects of Global Warming. *National Parks*, p. 24-29, July/August 1989.

Page reviews the current and anticipated effects of global climate change with special emphasis on the role of the National Park Service. The impact on the regional ecosystems in the temperate and higher latitudes is expected to be especially great. He notes, for example, the "paleobotanists have determined that beech forests followed the retreating ice of the last ice age at a rate of 20 kilometers a century." If temperatures rise at some of the predicted rates, beeches would have to move 500 kilometers north to find suitable climate. Even modest increases in sea level will have significant impacts on low-lying areas such as the Florida Everglades and coral reefs.

Rosenzweig, Cynthia. How It Might Be: Agriculture. *EPA Journal*, p. 9-10, January/February 1989.

Rosenzweig opens by observing that climate and agriculture are inextricably linked so the projected increase in temperatures and changes in precipitation patterns are likely to have large impacts on U.S. agriculture. A variety of factors such as better acclimated crop varieties may mitigate some of the negative climate effects. Increased carbon dioxide may directly benefit crops by increasing size and yield. On the other hand, warmer climates may mean that many crops will no longer be able to grow in the South, Midwest and Great Plains while agricultural production in Minnesota and the Great Lakes states may expand significantly. As agricultural regions shift northward with the warmer weather, crop pests and livestock diseases will follow. In warmer, drier regions increased demand for irrigation may produce (or increase) groundwater overdrafts. With these shifts will probably come dislocation of people, jobs, and environmental habitats.

Schell, Jonathan. Our Fragile Earth. *Discover*, p. 44-50, October, 1989.

This non-technical article begins with a brief review of the history and scientific background of the greenhouse effect. Schell goes on to discuss "the quandary of the scientists" who, on one hand, try to describe and predict climate change which is very complex and imperfectly understood, while on the other hand, understand that the only way to know certainly what will happen is to watch a global experiment which might bring about immense, catastrophic change.

Schneider, Claudine (R-R.I.) Turning Down the Heat: A Plan to Check the Rate of Global Warming. *National Parks*, p. 16-17, 42, July/August, 1989.

The author briefly reviews the basis for concern and a variety of possible effects of global warming. Included are descriptions of recent efforts at the international level such as the 1987 Montreal Protocol to reduce ozone-depleting chemicals; at the national level such as the proposed Global Warming Prevention Act (H.R.1078); and at the individual level such as participating in the Global Releaf program, recycling, and energy conservation in the home.

Schneider, Stephen H. The Changing Climate. *Scientific American*, p. 70-79, September, 1989.

Schneider presents an excellent overview of the greenhouse effect and carefully describes what is known as well as what is still to be learned about the dynamics of climate change. He then describes what current climate models are able to predict and reviews the effects in various sectors including agriculture. Finally, a variety of possible responses are examined with an assessment of the positive and negative aspects of each. At the present time the author foresees global warming of at least 1 to 2 degrees C because no plausible policies are available to prevent it. However, he is hopeful that some demonstrable change may in fact catalyze international cooperation.

Schneider, Stephen H. The Greenhouse Effect: Science and Policy. *Science*, p. 771-81, February 10, 1989.

This article describes in considerable detail the science behind the greenhouse effect and the state of knowledge (in 1989) about the complex dynamics which determine climate change. Increased concentrations of greenhouse gases, most apparently caused by human activity, will affect climate; the questions are how? and how much? Schneider also discusses the state of global climate modeling, both what can and cannot be done. Given the possible scenarios, he describes possible environmental and societal impacts. Finally, appropriate policy responses are outlined. The 77 references cited in the paper represent a significant review of the literature.

Sedjo, Roger A. Forests to Offset the Greenhouse Effect: If 'Planting Trees' Could Save Us, How Many Trees Would We Have To...? *Journal of Forestry*, p. 12-15, July 1989.

Trees and other plants play an important role in the climate process by converting the carbon component of carbon dioxide into biomass and releasing the oxygen into the atmosphere. This ability to sequester carbon means that the forests serve as a 'sink' for the carbon dioxide. Of course, if a tree burns or decays, it releases carbon dioxide back into the atmosphere. Also, while mature forests that experience little growth hold carbon, they sequester little additional carbon and are therefore not a major sink for atmospheric carbon. Current estimates suggest that atmospheric carbon dioxide is increasing at a rate of approximately 2.9 billion tons per year. Sedjo estimates that it would take approximately 465 million hectares of new fast-growing plantations to sequester that much carbon dioxide. Land requirements and economic costs are discussed. The author observes that such an approach would offer a means of postponing for 30-50 years the build-up of carbon dioxide.

Shukla, J., C. Nobre, and P. Sellers. Amazon Deforestation and Climate Change. *Science*, p. 1322-5, March 16, 1990.

In an effort to investigate the potential effects of Amazon deforestation on the regional physical climate system, the authors used a realistic model of the biosphere coupled with a realistic model of the atmosphere. Assuming that the deforested areas would be replaced by grasses, the simulation suggests a significant increase in surface temperature, reduced evapotranspiration and a decrease in precipitation. In addition, the model shows an increase in the length of the dry season which would make re-establishment of the forests very difficult.

Spencer, Roy W. and John R. Christy. Precise Monitoring of Global Temperature Trends from Satellites. *Science*, p. 1558-1562, March 30, 1990.

Atmospheric temperature data from satellite-based microwave sounding units were analyzed for a 10-year period, 1979-1988. These data are especially useful because they provide nearly complete earth coverage including the oceans and southern continents compared to the very limited and uneven distribution of surface thermometer sites. In addition, they provide measurements from various levels of the atmosphere. The authors conclude that while there was considerable temperature variability on time scales from weeks to several years, there was no obvious trend for the 10-year period.

Stein, Jay. Hydrogen: Clean, Safe, and Inexhaustible. *Amicus Journal*, p. 33-36, Spring 1990.

Among the many alternatives to fossil fuels now being examined is hydrogen. The product of hydrogen combustion is pure water and by using electrolysis, the process can be reversed to produce hydrogen and oxygen. Despite these advantages, however, more research needs to be done to find a more cost-effective means of producing hydrogen and a safer means of storing it on-board vehicles.

Trefil, James. Modeling Earth's Future Climate Requires Both Science and Guesswork. *Smithsonian*, v.21, p. 29-37, December, 1990.

Writing in a clear, jargon-free style, Trefil reviews what is known and what is not known about climate prediction and modeling. His insightful discussion of various models, assumptions, and our limited - though increasing - stock of climate knowledge help the reader to understand the conflicting predictions about global warming. General Circulation Models (GCMs) contain "minimodels' for each of the Earth's systems (ocean, atmosphere) each of which has its own set of assumptions as well as assumptions about how each system interacts. Nevertheless, despite all the defects and uncertainties, it is possible for scientists to come to some sort of consensus. The 200-300 scientists who contributed to the findings of the Intergovernmental Panel on Climate Change generally agree that a doubling of the greenhouse gases will result in a 3-to-8 degree warming.

Udall, James R. Turning Down the Heat. *Sierra*, p. 26-33. July/August 1989.

Udall cites a variety of U.S. and international authorities to demonstrate that there is widespread support for the idea that global warming is here. Included are two graphs which demonstrate a correlation between an increase in temperature and an increase in atmospheric carbon dioxide. Most of the article, however, addresses what should and can be done to reduce the emission of greenhouse gases. For those interested in figuring out what their own contributions are he provides a list of formulas for domestic calculations. According to Udall, the greatest difficulties in dealing with the problem are not the technological aspects but the political and social aspects which will require not only national resolve but genuine international cooperation.

White, David C., Clinton J. Andrews, and Nancy W. Stauffer. The New Team: Electricity Sources Without Carbon Dioxide. *Technology Review*, p. 42-50, January 1992.

The authors argue that researchers should stop "quibbling over how much global temperatures could rise," and put more effort into developing and implementing a mix of clean technologies. We could begin, for example, by using fossil fuels more efficiently with improved burning technologies. Next, we could work to improve carbon-free options such as nuclear fission; however, the authors note both political concerns and the as yet unresolved long-term storage issues. A third set of options would focus more research on renewable sources such as solar and hydrothermal energy. In order to bring about these changes, the authors suggest that funding agencies such as the U.S. Department of Energy should spread their budgets more uniformly to increase funding to renewable energy research from the current massive support for non-renewable energy research. Finally, the authors argue that environmental costs need to be figured into any energy investment strategies of government or business.

White, Robert M. Greenhouse Policy and Climate Uncertainty. *Bulletin American Meteorological Society*, p. 1123-1127, September 1989.

White provides an assessment of both the quantity and quality of information in the "knowledge base" on the impact of greenhouse gases on the climate system. He carefully distinguishes between scenarios that provide a range of credible possibilities, and forecasts that predict. He concludes with an examination of policy principles in an environment where "knowledge and information are being continually refreshed by new findings and interpretations and our assessment of risk and uncertainties are continually changing."

Global Change Information Resources

Second edition
September 1992

National Agricultural Library

U.S. Department of Agriculture

Beltsville, MD 20705

DIRECTORY OF ORGANIZATIONS CONCERNED WITH GLOBAL CLIMATE CHANGE

Compiled by

Janet Wright
Head, D.C. Reference Center
National Agricultural Library

This directory lists organizations which are primarily concerned with issues related to global climate change. Reasonable care was taken to ensure the accuracy and completeness of this listing, but the number of such organizations continues to grow. If you know of organizations which are not included but should be, please write or call Janet Wright, D.C. Reference Center, National Agricultural Library, Rm. 1052-S, 14th and Independence Aves. SW, Washington, DC 20250. Tel:(202)720-3434.

Contents

Carbon Dioxide Information Analysis Center

Oak Ridge National Laboratory
Building 1000, MS 5335
P.O. Box 2008
Oak Ridge, TN 37831-6335

Robert M. Cushman, Dir.
Tel: (615) 574-0390
Fax: (615) 574-2232

E-mail: BITNET: CDP@ORNLSTC Internet: CDP@STC10.CTD.ORNL.GOV
OMNET: CDIAC

Founded: 1982
Funding and Organization: Sponsored by the U.S. Department of Energy's Carbon Dioxide Research Program. The Oak Ridge National Laboratory is managed by Martin Marietta Energy Systems, Inc. for the U.S. Department of Energy.
Mission: To develop sound scientific information for the evaluation of policy and government action in response to changes in emissions and atmospheric concentrations of carbon dioxide and other greenhouse gases and resulting climate change.
Activities: Obtains, evaluates, and distributes data associated with carbon dioxide, other trace gases and climate.
Publications: "CDIAC Communications" (newsletter published three times per year); "DOE Research Summary" (four-page monthly highlight of current DOE-funded research); "Trends 91: A Compendium of Data on Global Change"; "Glossary: Carbon Dioxide and Climate." All are available free.

Center for Environmental Information, Inc.

46 Prince St.
Rochester, NY 14607

Elizabeth Thorndike, Dir.
Tel: (716) 546-3796
Fax: (716) 325-5131

Founded: 1975
Members: 657
Funding and Organization: Private, non-profit.
Mission: To furnish timely, accurate and comprehensive information on environmental issues.
Activities: Gathering and disseminating information. Maintains library open to the public. Provides bibliography on any environmental subject for a small fee.
Publications: Global Climate Change Digest (monthly); Acid Precipitation Digest (monthly); CEI Sphere (bimonthly, for members only).

Center for Global Change

University of Maryland
Executive Building, Suite 401
7100 Baltimore Avenue
College Park, MD 20740

Alan Miller, Exec. Dir.
Christopher Fox, Asst. Dir.
Tel: (301) 403-4165
Fax: (301) 403-4292

Founded: 1989
Meetings/Conventions: Sponsors conferences two or three times per year.
Funding and Organization: Initially funded by a $1.8 million grant from the Environmental Protection Agency. Additional funding received from foundations, state and national governments and agencies, and private sources.
Mission: To bring together scientists and policy analysts from a range of fields to study environmental quality issues and their relationship to energy use and economic growth; to conduct research assessing the risk of environmental degradation and to investigate technologies and policies to reduce it; the Center's initial priorities include programs dealing with ozone depletion, global climate change and sea level rise; to disseminate its research. The Center neither litigates nor lobbies.
Activities: Coordinates the ongoing research of the University of Maryland scientists. Provides small project grants to graduate students and professors who want to begin research on global change problems. Sponsors international conferences and symposiums. Is now compiling catalogue of state and local laws aimed at slowing global warming.
Publications: Publishes articles in various publications. A listing of publications is available upon request.

Clean Energy Research Institute
University of Miami

219 McArthur Building
University of Miami
P.O. Box 248294
Coral Gables, FL 31124

Dr. T. Nejat Veziroglu, Dir.
Tel: (305) 284-4666

Founded: 1974
Members: 2,500
Staff: 168
Meetings: Two conferences per year.
Organization and Support: Part of University of Miami's College of Engineering; directed by an international council of scientists. Funded by University of Miami, U.S. government, various foundations and industries.
Mission: To research and record environment-related energy problems.

(**Clean Energy Research Institute**, continued)

Activities: Studies solar energy, hydrogen energy, synthetic fuels, acid rain and the greenhouse effect. Disseminates information through conferences (including the annual Miami International Conference on Alternative Energy Sources), workshops, reports and journal articles.
Publications: Conference Proceedings, annual report and various journal articles.

Climate Institute

324 Fourth St., NE
Washington, DC 20002

John C. Topping, Jr., Pres.
Tel: (202) 547-0104
Fax: (202) 547-0111
Tlx: 214 858 CLIMATE UR

Founded: 1986
Funding and Organization: Funded by individual and institutional membership fees and the sale of informational products.
Mission: To increase understanding of global warming and stratospheric ozone depletion.
Activities: Sponsors regional conferences and workshops on climate change. Produces reports, conference proceedings and other information products.
Publications: Climate Alert (qtly newsletter); conference proceedings and monographs.

Cooperative Institute for Research in the Atmosphere

Colorado State University
Foothills Campus
Fort Collins, CO 80523

Thomas H. Vonder Haar, Dir.
Tel: (303) 491-8448

Founded: 1980
Staff: 54
Funding and Organization: Separately incorporated institution sponsored by Colorado State University and by the National Oceanic and Atmospheric Administration. Receives support from the National Oceanic and Atmospheric Administration, National Park Service, National Science Foundation, the Office of Naval Research, and the National Aeronautics and Space Administration.
Mission: To increase the effectiveness of atmospheric research of mutual interest to NOAA, CSU, the state and the nation; to provide a research center for scientists which will facilitate cooperation on specified programs and hasten the training of atmospheric scientists.

(**Cooperative Institute for Research in the Atmosphere**, continued)

Activities: Conducts research on global weather patterns and their effects on agriculture, economics and society. Concentrates specifically on air quality, cloud physics, mesoscale studies and forecasting, satellite applications, climate studies, agricultural meteorology, and model evaluation. Sponsors workshops and makes presentations to outside groups.
Publications: Publishes research results in various professional journals. Annual report. Newsletter.

Cooperative Institute for the Remote Sensing of Biogeophysical Processes

Complex Systems Research Center
University of New Hampshire
Durham, NH 03824
and
Earth Sciences Dept.
Dartmouth College
Hanover, NH 03755

Barrett N. Rock, Co-director at University of New Hampshire
Tel: (603) 862-1792

Richard Birnie, Co-director at Dartmouth College
Tel: (603) 646-2666

Founded: 1986
Staff: 22
Organization and Support: Funded by the National Oceanic and Atmospheric Administration, and various industries and foundations.
Mission: To monitor, record and correlate changes in earth's vegetation and weather.
Activities: Uses satellite data and ground measuring and monitoring to map and document the change in forest conditions and ecosystem functions in the northeastern United States. Studies the effect of the deforestation of the Brazilian rainforest on cloud cover patterns, world-wide weather systems, and the global carbon cycle. Studies recorded weather patterns and aerial photography/satellite datasets of the last 40 years to determine changes which are taking place in the White Mountains of New Hampshire.
Publications: Publishes articles in subject journals and in proceedings of conferences. For more information contact the Directors.

Concern, Inc.

1794 Columbia Road, NW
Washington, DC 20009

Susan Boyd, Exec. Dir.
Tel.: (202) 328-8160
Fax: (202) 387-3378

(Concern, Inc., continued)

Founded: 1970
Funding and Organization: Private, non-profit.
Mission: Supply citizens with the information they need to pursue safe solutions to problems that threaten the environment and public health at the local, state, and national levels.
Activities: Provides environmental information to individuals, community groups, educational institutions, public officials and others involved with the environment, public education, and policy development.
Publications: Provides list of publications on request.

Environmental Action, Inc.

6930 Carroll Avenue #600
Takoma Park, MD 20770

Ruth N. Caplan, Exec. Dir.
James Tillman, Public Information Specialist
Tel: (301) 891-1100

Founded: 1970
Members: 15,000
Staff: 20
Budget: $1.25 mil.
Funding and Organization: Private, non-profit. The Environmental Action Foundation provides technical assistance on complex issues.
Mission: To enhance the compatibility of humanity and the environment by preventing pollution, reducing the use of nonrenewable resources, encouraging the conservation of energy and materials, and eliminating threats to natural cycles.
Activities: Lobbies Congress, makes campaign contributions, offers information through a hotline and other means. Helps organize at the grass roots level.
Publications: Environmental Action Magazine (bimonthly); list of publications available upon request.

Environmental Defense Fund

257 Park Avenue South
New York, NY 10010

Frederick D. Krupp, Exec. Dir.
Chris Magerl, Information Contact
Tel: (212) 505-2100
Fax: (212) 505-2375

Founded: 1967
Members: over 200,000

(**Environmental Defense Fund**, continued)

Staff: 107
Budget: $17.8 mil.
Meetings/Conventions: Annual Board of Trustees meeting.
Funding and Organization: Private, non-profit. Five regional offices.
Mission: To link science, economics and law to create innovative, economically viable solutions to environmental problems.
Activities: Initiates and supports legal action in defense of the environment. Uses innovative strategies to advocate environmental plans that help answer society's needs--wrote the sulfur emissions-trading section of the Clear Air Act; established task force with McDonald's to study ways to reduce the company's waste. Promotes environmental awareness by supporting research and public education.
Publications: Annual Report. EDF Letter (bimonthly). Numerous papers, pamphlets and articles and books on the subjects of acid rain, toxic and hazardous materials, biotechnology, global climate change, solid wastes and recycling,and wildlife conservation. A listing of current publications in print will be sent upon request.

Friends of the Earth

530 Seventh Street, SE
Washington, DC 20003

Mike Clark, Exec. Dir.
Kaiki Kehoe, Public Information Officer
Tel: (202) 544-2600

Founded: 1969
Members: 15,000
Staff: 22
Budget: $350,000
Funding and Organization: Private, non-profit. Affiliated with Friends of the Earth Foundation and Friends of the Earth International.
Mission: To advocate the preservation, restoration, and rational use of the earth's resources.
Activities: Lobbies Congress and participates in law making and monitoring activities. Conducts research and disseminates information through a variety of ways.
Publications: Not Man Apart (newsletter, bimonthly); books, articles and pamphlets. Listing available upon request.

Global Foundation, Inc.

P.O.Box 24-8103
Coral Gables, FL 33124-8103

Dr. Behram N. Kursunoglu, Chairman
Linda F. Scott, Executive Assistant to the President
Tel: (305) 284-4458

Founded: 1977
Staff: 4
Budget: $200,000
Funding and Organization: Independent, not-for-profit organization. Funded by the U.S. government, foundations, businesses and membership fees and gifts of individual and institutional members.
Mission: To conduct research and disseminate information and to support research and work being done by other institutions concerning major global problems including energy and international environmental problems, arms non-proliferation.
Activities: Brings senior men and women of science and learning and outstanding achievers and entrepreneurs from industry, government, and international organizations together with promising and enthusiastic young people to work together on solutions to major world problems and problems on the frontiers of science. Sponsors lectures, workshops, and conferences (including the annual International Scientific Forum on Energy). Sponsors university courses on nuclear issues, energy, and environment.
Publications: Various books and papers, news releases, proceedings of seminars, workshops, conferences and international forums.

Global Releaf

The American Forestry Association
P.O. Box 2000
Washington, DC 20013

Sally Caudill, Public Relations
(202) 667-3300

Founded: 1988
Mission: To improve the earth's environment by promoting more and better trees and forests through a national education, action and policy campaign.
Activities: Sponsors tree planting program through phone in orders, $5 per call, 1-900-420-4545.
Publications: Global Releaf Action Guide. Global Releaf Report.

Global Tomorrow Coalition

1325 G Street NW
Suite 1010
Washington, DC 20005-3104

Donald R. Lesh, Pres.

Tel: (202) 628-4016
Fax: (202) 628-4018

Founded: 1981
Members: 750
Funding and Organization: Private, non-profit coalition of organizations and individuals.
Mission: Provide a non-partisan forum at the cutting edge of social and political change, for the leaders of key constituencies -- civic organizations, business, science and technology, education, religion, and government -- to build national consensus on sustainable development goals and practical strategies to attain them.
Activities: Assists in organizing public forums. Briefs U.S. policymakers on global issues in order to further U.S. leadership on the environment. Serves as a clearinghouse for the public policy programs of member organizations. Maintains a speakers' bureau.
Publications: Global Tomorrow Coalition - Interaction, newsletter; The Global Ecology Handbook, curriculum sets.

Greenhouse Crisis Foundation

1130 Seventeenth St. NW
Suite 630
Washington, DC 20036

Jeremy Rifkin, Pres
Tel: (202) 466-2823
Fax: (202) 429-9602

Founded: 1988
Funding and Organization: Private, non-profit.
Mission: To focus public attention on the threat of global warming and related atmospheric problems - such as ozone depletion and acid rain.
Activities: Supports the Greenhouse Crisis Education Campaign and the Beyond Beef Campaign. Sponsors the International Local Government Network, the Global Greenhouse Network, and the Center for Sustainable Transportation.
Publications: A Citizens Guide: 101 Ways to Help Heal the Earth, The Green Lifestyle Handbook, and Voting Green. Also an information packet on global warming.

Greenpeace USA

1436 U Street NW
Washington, DC 20009

Peter Bahouth, Exec. Dir.
Sanjay-mishra, Public Information Coordinator
Tel: (202) 462-1177
Fax: (202) 462-4507
Tlx: 89-2359

Founded: 1971
Members: 1.8 million
Staff: 47
Meetings: Quarterly Board meeting.
Funding and Organization: Five regional groups. Affiliated with Greenpeace International. Private, non-profit.
Mission: To preserve the earth and the life it supports; to halt the needless slaughter of endangered species; to protect the environment from nuclear and toxic pollution; to stop the threat of nuclear war.
Activities: Monitors toxic waste dumping and acid rain levels. Participates in an international campaign to stop the testing of nuclear weapons. Protects the diversification of animal and plant life through non-violent civil disobedience when necessary; tries to prevent the harpooning of whales and the hunting of seals by placing themselves between the hunters and the animals. Conducts wildlife campaigns and ocean ecology research.
Publications: The Greenpeace Magazine; Greenpeace Examiner (qtly); factsheets.

Illinois Global Climate Change Program

Illinois State Water Survey
2204 Griffith Dr.
Champaign IL 61820

Dr. Stanley A. Changnon, Dir.
Dr. Stephen J. Vermette, Asst. Dir.

Founded: 1991
Funding and Organization: Supported by the Illinois State Water Survey, a Division of the Department of Energy and Natural Resources. Additional funding obtained from external institutions through grants, contracts and cooperative agreements.
Mission: To provide for Illinois and the Midwest a center of expertise addressing the global climate change issue with a three-way focus, including studies of climate change and its effects, monitoring of climate-related environmental changes, and the timely dissemination of information about the issue.
Activities: Conducts research on climate change, in particular the impacts of change on the environment, industry, and socioeconomic concerns. Aside from specific physical areas and economic sectors, it promotes multidisciplinary projects to investigate regional-scale impacts of climate change. Regional studies

(Illinois Global Climate Change Program, continued)

include the Chicago metropolitan area, the Great Lakes basin, and the Illinois River basin. Develops projects to detect and measure climate change and its effects on Illinois and the Midwest. The Water Survey library has established a special collection housing publications related to climate change and its effects.

Publications: Provides updated data and information on climate change through various brochures, fact sheets, publications, meetings and conferences. Publishes articles in various scientific journals; By Degrees (a series of fact sheets); a series of publications on impacts of change and policy implications (i.e. impacts of climate on the crop-weather insurance industry); The Plan for the Illinois Global Climate Change Program; miscellaneous brochures.

NASA Master Directory

The National Space Science Data Center
Code 633
NASA Goddard Space Flight Center
Greenbelt MD 20771

Tel: (301) 794-5186
Fax: (301) 794-7106

Founded: 1989

Funding and Organization: Sponsored and coordinated by NASA and the Interagency Working Group on Data Management for Global Change (IWGDMGC), a joint effort by NASA, NOAA, USGS, and other government agencies and universities. Funded by NOAA. Database input and management by NASA, NOAA, USGS, and other government agencies, universities and private organizations.

Mission: To enable researchers to efficiently identify, locate, and obtain access to space and earth science data.

Activities: Maintains a free multidisciplinary computerized directory to earth and space science databases; dial-up access, keyword searching, menu driven, no password required. Provides automatic connections to other databases as appropriate. Accessible through SPAN, Internet and OMNET, or via direct dial (301) 286-9000. Enter number: MD; Username: NSSDC. Questions in specific subject areas should be directed to subject specialists:

Astronomy -- Paul Kuin
Atmospheric Sciences -- John Scialdone
Geology -- Joy Beier
Oceanography -- David Irvine
Planetary Sciences -- Neil Cline
User Support -- Janis Shipe

North American Association for Environmental Education

P.O. Box 400
Troy, OH 45373

Edward J. McCrea, Exec. Dir.
Tel: (513) 339-6835

Founded: 1971
Members: 1500
Meetings/Conferences: 1992 - Toronto Canada
1993 - Big Sky, MT
Funding and Organization: A professional association of educators and administrators.
Mission: To assist and support the work of those engaged in environmental education.
Publications: Environmental Communicator (bimonthly newsletter).

Resources for the Future

1616 P Street N.W.
Washington DC 20036

Robert W. Fri, Pres.
K. Stork, Public Affairs Manager
Tel: (202) 328-5006

Founded: 1952
Staff: approx. 100
Budget: $7.5 mil.
Organization and Support: Independent, non-profit. Established with the cooperation of the Ford Foundation and supported by endowments and grants from foundations, government agencies and corporations. Grants are accepted on the condition that RFF is solely responsible for the conduct of its research and the dissemination of its work to the public.
Mission: Seeks to inform and improve policy debates about resource and environmental issues to those involved in shaping policy, to academics, and to members of the interested public. Maintains a nonpartisan, objective stance on all specific policy issues at the same time that it advocates more efficient, equitable, and effective policies in general.
Activities: Conducts research and education on environmental and natural resource issues. Provides support to research through visiting appointments to its staff and through grants and fellowships to scholars elsewhere. Holds conferences and colloquia on resource and environmental issues. Sponsors weekly noon-time seminars during the academic year. Arranges policy briefings for members of Congress, business leaders, the media and the non-profit community. Does not take positions on laws, policies, or events, nor does it lobby.
Publications: Publishes extensively in the areas of energy and natural resources, environment, and risk management. Over 120 titles currently available. For a catalog, contact Manager of Book Marketing, (202) 328-5086.

World Resources Institute

1709 New York Avenue, NW
Washington, DC 20006

James Gustave Speth, Pres.
Tel: (202) 638-6300
Fax: (202) 638-0036
Tlx: 64414 WRIWASH

Founded: 1982
Staff: 90
Organization and Support: Independent, non-profit, and nonpartisan.
Mission: Created to help answer the question: How can societies meet human needs and nurture economic growth while preserving natural resources and environmental integrity?
Activities: Sponsors policy research, seminars, intern program and maintains library.
Publications: World Resources Report; various reports and books.

Global Change Information Resources

Second edition
September 1992

GLOBAL CLIMATE CHANGE PATHFINDER; A Guide to Information Sources

Chestalene Pintozzi and Douglas E. Jones
Science-Engineering Library
The University of Arizona
Tucson, Arizona

This pathfinder is a guide to the more scientific and technical aspects of global climate change including meteorological and climatological aspects; biological, agricultural, and public policy implications; and the chemical processes involved. Sources are arranged by type of publication. Some sections include selected bibliographies with emphasis on recent publications. For additional information or for assistance with using the sources listed here, please consult a librarian at your local library.

Contents

National Agricultural Library

U.S. Department of Agriculture

Beltsville, MD 20705

REFERENCE SOURCES

Bair, Frank E., editor. *The Weather Almanac*. 6th ed. Detroit: Gale Research Co., 1992.
See "The Climatic System and Processes of Climatic Change," pp. 345-58 and "The Carbon Dioxide Problem," pp. 349-354.

Brackley, Peter, editor. *World Guide to Environmental Issues and Organizations*. London: Longman Group UK Limited, 1990. 386 p.
Useful entries include: Deforestation, pp. 42-51; The greenhouse effect and global warming, pp.52-65; and Organizations, pp. 256-356.

Fairbridge, Rhodes W. and John E. Oliver, editors. *The Encyclopedia of Climatology*. New York: Van Nostrand Reinhold, 1987. Encyclopedia of Earth Sciences v. 11.
Useful entries include: Carbon dioxide and climate, pp. 185-195; Climatic modification, inadvertent, pp. 287-293; Climatic change theories, pp. 212-221; Greenhouse effect, pp. 463-465; and Energy budget climatology, pp. 415-421. Each entry has a bibliography and cross references to other related entries.

Goldsmith, Edward and Nicholas Hildyard, editors. *The Earth Report: the Essential Guide to Global Ecological Issues*. 240 p. Los Angeles, CA: Price, Stern, Sloan, 1988.

Hatch, Warren L. *Selective Guide to Climatic Data Sources*. Washington, D.C.: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1983. Key to Meteorological Records Documentation number 4.11.

Houghton, David D., editor. *Handbook of Applied Meteorology*. New York: Wiley, 1985.
Contains chapters on climatology, measurements, and societal impacts. Other subjects of interest may be found in the index.

Landsberg, H. E., editor. *General Climatology*. 3 volumes. New York: Elsevier, 1969-1985. World Survey of Climatology volumes 1-3.
Provides general background information on many aspects of climatology including climatic fluctuations.

McGraw-Hill Encyclopedia of Science and Technology, 7th ed. 20 volumes. New York: McGraw-Hill, 1992.
See index under: Climate Modeling; Climate Modification; Climatic Change; and Greenhouse Effect.

McGraw-Hill Yearbook of Science and Technology 1991. New York: McGraw-Hill, 1990.
See Hansen, James. Greenhouse Effect pp. 176-78.

State of the World, 1992: A Worldwatch Institute Report on Progress Toward a Sustainable Society. New York: Norton, 1992. 256 p.

Tables include world fossil fuel use and carbon emissions for 1990.

BIBLIOGRAPHIES

Carbon Dioxide and Climate, January 1970-August 1989. (Citations from the NTIS Database). Springfield, VA: National Technical Information Service, 1989. PB89869382

Carbon Dioxide and Climate, January 1970-July 1989. (Citations from Pollution Abstracts). Springfield, VA: National Technical Information Service, 1989. PB89869390

Christensen, John O. *Greenhouse Effect and Public Policy: a Selective Bibliography of Recent References*. Monticello, IL: Vance Bibliographies, 1991. 18 p. Public Administration Series: Bibliography P3071.

Doornkamp, John C. *Global Warming: Climate Change and Rising Sea-Levels: A Bibliography.* Long Eaton, England: M1 Press, 1990. 74p.

Earth Observations and Global Change Decision Making: A Special Bibliography. Washington, D.C.: National Aeronautics and Space Administration, 1991. 93 p. NASA SP7092

Global Change and Climate History Program: Bibliography Fiscal Years 1987-1991. Reston, VA: U.S. Geological Survey, Geologic Division, 1991. 29 p.

Global Warming, January 1988-March 1991. (Citations from the NTIS Database). Springfield, VA: National Technical Information Service, 1991. PB91800003

Lockerby, Robert W. *Climatic Change and Global Warming: a Selected Bibliography.* Monticello, IL: Vance Bibliographies, 1989. 22 p. Public Administration Series: Bibliography P2633.

MacLean, Jayne T. *Global Warming and the Greenhouse Effect: January 1979 - February 1990.* Beltsville, MD: National Agricultural Library, 1990. Quick Bibliography Series: QB 90-56

MacLean, Jayne T. *Global Warming and the Greenhouse Effect: January 1986 - January 1992.* Beltsville, MD: National Agricultural Library, 1992. Quick Bibliography Series: QB 92-36.

Nordquist, Joan, editor. *The Greenhouse Effect: a Bibliography.* Reference Research Service, 1990. Contemporary Social Issues: a Bibliographic Series, no. 18.

Wright, Peter B. *Portrait of Climatic Change; A Survey of the Field and a Review of Recent Books*. Norwich, England: T.D. Davies (PCC), 1977. 46 p.

This bibliography is useful for locating historical works on climatic change.

BOOKS

Subject Headings: Two sets of subject headings, Library of Congress and Sears, are widely used in libraries in the United States. A librarian at your local library can tell you which is used there and help you select headings from the lists below, or suggest other subject headings, that will lead you to books on aspects of climate change that interest you.

Library of Congress	Sears
GLOBAL WARMING	CLIMATE
GREENHOUSE EFFECT, ATMOSPHERIC	METEOROLOGY
CLIMATIC CHANGES	WEATHER
GLOBAL TEMPERATURE CHANGES	ATMOSPHERE
CARBON CYCLE (BIOGEOCHEMISTRY)	POLLUTION
ATMOSPHERIC CARBON DIOXIDE	MAN--INFLUENCE ON NATURE
POLLUTION, ENVIRONMENTAL ASPECTS	ENVIRONMENT--GOVERNMENT POLICY
CROPS AND CLIMATE	FOREST INFLUENCES
MAN--INFLUENCE ON NATURE	
GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE	

Introductory Works

Abrahamson, Dean E., editor. *The Challenge of Global Warming*. Washington, D.C.: Island Press, 1989. 358 p.

Bernard, Harold. *The Greenhouse Effect*. Cambridge, MA: Ballinger, 1980. 189 p.

Erickson, Jon. *Greenhouse Earth; Tomorrow's Disaster Today*. Blue Ridge Summit, PA: Tab Books, 1990. 167 p.

Fisher, David E. *Fire and Ice: the Greenhouse Effect, Ozone Depletion, and Nuclear Winter*. New York: Harper and Row, 1990. 232 p.

Gribbin, John R. *Future Weather: Carbon Dioxide, Climate and the Greenhouse Effect*. New York: Penguin Books, 1983. 302 p.

Gribbin, John R. and Kelly, Mick. *Winds of Change: Living in the Global Greenhouse*. London: Headway, 1989. 162 p.

Leggett, Jeremy. *Global Warming: The Greenpeace Report*. New York: Oxford University Press, 1990. 554 p.

Oppenheimer, Michael. *Dead Heat: the Race Against the Greenhouse Effect*. New York: Basic Books, 1990. 268 p.

Revkin, Andrew. *Global Warming: Understanding the Forecast*. New York: Abbeville Press, 1992. 180 p.

Schneider, Stephen H. *Global Warming: Are We Entering the Greenhouse Century?* San Francisco: Sierra Club Books, 1989. 317 p.

Tesar, Jenny E. *Global Warming*. New York: Facts on File, Inc., 1991. 112 p.

Selected Books

Bach, Wilfred. *Modeling the Influence of Carbon Dioxide on the Global and Regional Climate: Methodology and Results*. Paderborn, Federal Republic of Germany: Ferdinand Schoningh, 1985. 114 p.

Barth, Michael C. and James G. Titus. *Greenhouse Effect and Sea Level Rise: A Challenge for This Generation*. New York: Van Nostrand Reinhold, 1984. 324 p.

Bennett, Robert and Robert Estall, editors. *Global Change and Challenge: Geography for the 1990s*. New York: Routledge, 1991. 264p.

Bolin, Bert, et al. *The Greenhouse Effect, Climatic Change and Ecosystems*. Chichester [West Sussex]; New York: Published on behalf of the Scientific Committee on the Problems of the Environment of the International Council of Scientific Unions by Wiley, 1986. 541 p. SCOPE Report 29.

Budyko, M. I. and Yu. A. Izrael, editors. *Anthropogenic Climate Change*. Tucson, AZ: University of Arizona Press, 1991. 485 p.

Churchill, Robin and David Freestone. *International Law and Global Climate Change*. Boston: Graham and Trotman, 1991. 447 p.

Climate, Climatic Change and Water Supply. Washington, D.C.: National Academy of Sciences, 1977. 132 p.

Committee on Science, Engineering, and Public Policy (U.S.). Policy Implications of Greenhouse Warming--Synthesis Panel. *Policy Implications of Greenhouse Warming.* Washington, D.C.: National Academy Press, 1991, 127 p.

Corell, Robert W. and Patricia A. Anderson. *Global Environmental Change.* New York: Springer-Verlag, 1991. 264 p. NATO ASI Series. Series I: Global Environmental Change, V.1.

Edgerton, Lynne T. *The Rising Tide: Global Warming and World Sea Levels.* Washington, D.C.: Island Press, 1991, 140p.

Edmonds, J. A. et al. *Future Atmospheric Carbon Dioxide Scenarios and Limitation Strategies.* Park Ridge, NJ: Noyes Publications, 1986. 620 p.

Energy and Climate Change: Report of the DOE Multi-Laboratory Climate Change Committee. Chelsea, MI: Lewis Publishers, Inc., 1990. 161 p.

Firth, Penelope and Stuart G. Fisher, editors. *Global Climate Change and Freshwater Ecosystems.* New York: Springer-Verlag, 1992. 321 p.

Ford, Michael J. *The Changing Climate: Responses of the Natural Flora and Fauna.* London: Allen and Unwin, 1982. 190 p.

Gore, Albert. *Earth in the Balance: Ecology and the Human Spirit.* Boston: Houghton Mifflin, 1992. 407 p.

Hansen, J. E. and Taro Takahashi, editors. *Climate Processes and Climate Sensitivity.* Washington, D.C.: American Geophysical Union, 1984. 368 p.

Intergovernmental Panel on Climate Change. *Climate Change: The IPCC Impacts Assessment.* Canberra: Australian Government Publishing Service, 1990.

Intergovernmental Panel on Climate Change. *Climate Change: The IPCC Response Strategies.* Washington, D.C.: Island Press, 1991. 272 p.

Intergovernmental Panel on Climate Change. *Climate Change: The IPCC Scientific Assessment.* New York: Cambridge University Press, 1990. 364 p.

MacCracken, Michael C. et al., editors. *Prospects for Future Climate: A Special US/USSR Report on Climate and Climate Change.* Prepared under the auspices of the US/USSR Agreement on Protection of the Environment. Chelsea, MI: Lewis Publishers, Inc., 1990. 270p.

Mather, John R. and Galina V. Sdasyuk, editors. *Global Change: Geographical Approaches.* Tucson, AZ: University of Arizona Press, 1991. 289 p.

Parry, Martin L.; Timothy R. Carter; and Nicolaas T. Konijn, editors. *The Impact of Climatic Variations on Agriculture. Volume 1: Assessments in Cool, Temperate and Cold Regions. Volume 2: Assessments in Semi-Arid Regions*. Dordrecht; Boston: Kluwer Academic, 1988. v.1, 876 p. v.2, 764 p.

Pearce, D. et al. *Climate Change: Evaluating the Socio-Economic Impacts*. Paris: Organization for Economic Cooperation and Development, 1991. 109 p.

Reilly, John M. and Margot Anderson, editors. *Economic Issues in Global Climate Change: Agriculture, Forestry, and Natural Resources*. Boulder, CO: Westview Press, 1992. 460 p.

Roan, Sharon. *Ozone Crisis: the 15-Year Evolution of a Sudden Global Emergency*. New York: Wiley, 1989. 270 p.

Shands, William E. and John S. Hoffman, editors. *The Greenhouse Effect, Climate Change, and U.S. Forests*. Washington, D.C.: Conservation Foundation, 1987. 304 p.

Singer, S. Fred, editor. *Global Climate Change: Human and Natural Influences*. New York: Paragon House Publishers, 1989. 424 p.

Smith, Joel B. and Dennis A. Tirpak. *The Potential Effects of Global Climate Change on the United States*. New York: Hemisphere Publishing Corporation, 1990. 689 p.

Thompson, Peter, editor. *Global Warming: The Debate*. New York: Wiley, 1991.

Trexler, Mark C. *Minding the Carbon Store: Weighing U.S. Forestry Strategies to Slow Global Warming*. Washington, D.C.: World Resources Institute, 1991. 81 p.

Waggoner, Paul E. *Climate Change and U. S. Water Resources*. New York: Wiley, 1990.

Wuebbles, Donald J. and Jae Edmonds. *Primer on Greenhouse Gases*. Chelsea, MI: Lewis Publishers, Inc., 1991. 230 p.

Wyman, Richard L., editor. *Global Climate Change and Life on Earth*. New York: Routledge, Chapman and Hall, 1991, 282p.

INDEXES AND ABSTRACTS
Including Online and CD-ROM Databases

The following sources will lead to additional information in journal articles and other information sources. Most of these sources are also available as online databases that may be accessible through your local library. If a database is also available on CD-ROM, this is noted at the end of the listing. For help in selecting an index that includes the aspects of global warming that you are researching, please ask a librarian at your local library.

Applied Science and Technology Index. V.1 - , 1913 - . New York: H. W. Wilson Company.
Relevant subject headings include: GREENHOUSE EFFECT, ATMOSPHERIC OZONE, DEPLETION OF; and CLIMATIC CHANGES.
Available on CD-ROM.

Bibliography of Agriculture. V.1 - , 1942 - . Phoenix, AZ: Oryx Press.
Relevant subject headings include: CLIMATIC CHANGES; CLIMATIC FACTORS; GREENHOUSE EFFECT, ATMOSPHERIC; AIR POLLUTION ENVIRONMENTAL ASPECTS; and GLOBAL WARMING.
Available on CD-ROM.

Biological Abstracts. V.1 - , Dec. 1926 - . Philadelphia: BIOSIS.
Relevant keywords include: GLOBAL WARMING; GREENHOUSE EFFECT; and GREENHOUSE GASES.
Available on CD-ROM.

Biological and Agricultural Index. 1964 - . New York: H. W. Wilson Company.
Relevant subject headings include: GREENHOUSE EFFECT; FORESTS AND CLIMATE; SOILS, EFFECT OF CLIMATE ON; CLIMATE, EFFECT ON PLANTS; CLIMATE, EFFECT ON CATTLE; and other subdivisions of CLIMATE.
Available on CD-ROM.

Chemical Abstracts. V.1 - , 1907 - . Columbus, OH: American Chemical Society.
Relevant subject headings include: GREENHOUSE EFFECT and CLIMATE.

Environment Abstracts. V.1 - , Jan. 1971 - . New York: EIC Intelligence Publishing.
Relevant subjects include: CLIMATIC CHANGES and GREENHOUSE EFFECT.

Environmental Periodicals Bibliography. V.1 - , March 1972. - . Santa Barbara, CA: Environmental Studies Institute.
Relevant subject headings include: CLIMATE CHANGE; CLIMATIC CHANGE; GLOBAL TEMPERATURE INCREASE; GLOBAL WARMING and GREENHOUSE EFFECT.

General Science Index. V.1 - , 1978/79 - . New York: H. W. Wilson Company.
Relevant subject headings include: GREENHOUSE EFFECT and CLIMATIC CHANGES.
Available on CD-ROM.

Global Climate Change Digest: a Guide to Current Information on Greenhouse Gases and Ozone Depletion. 1988 - . New York: Elsevier Science Pub. Co.

International Environment Reporter, 1978 - . Washington, D.C.: Bureau of National Affairs.
Covers environmental law in major industrial nations.

Meteorological and Geoastrophysical Abstracts. V.1- , Jan. 1950- . Boston: American Meteorological Society.
Relevant subject headings include: ATMOSPHERIC GREENHOUSE EFFECT; BIOLOGICAL EFFECTS OF CLIMATIC FACTORS; CARBON DIOXIDE EFFECTS ON CLIMATE; ATMOSPHERIC POLLUTION EFFECTS ON CLIMATE; and several subdivisions under CLIMATE.

Oceanic Abstracts. V.1 - , 1965 - . Bethesda, MD: Cambridge Scientific Abstracts.
Relevant subject headings include: CLIMATIC CHANGES and GREENHOUSE EFFECT.

PAIS (Public Affairs Information Service) Bulletin. V.1- , 1915- . New York: Public Affairs Information Service.
Relevant subject headings include: GREENHOUSE EFFECT, ATMOSPHERIC and CLIMATE.
Available on CD-ROM.

Physics Abstracts. v.69- , 1966- . London: Institution of Electrical Engineers. Science Abstracts. Series A.
Relevant subject headings include: CLIMATOLOGY and ATMOSPHERIC TEMPERATURE.
Available on CD-ROM.

Pollution Abstracts. V.1 - , May 1970 - . Bethesda, MD: Cambridge Scientific Abstracts.
Relevant subject headings include: CLIMATE and CARBON DIOXIDE.
Available on CD-ROM.

Readers' Guide to Periodical Literature. V.1 - , 1900 - . NY: H. W. Wilson Company.
Relevant subject headings include: GREENHOUSE EFFECT and CLIMATIC CHANGES.
Available on CD-ROM.

Science Citation Index. 1961 - . Philadelphia: Institute for Scientific Information.

Relevant keywords include: CLIMATIC CHANGE; GLOBAL WARMING; GREENHOUSE EFFECT and GREENHOUSE GASES.

Available on CD-ROM.

Selected Water Resources Abstracts. V.1 - , Jan. 1968 - . Springfield, VA: National Technical Information Service.

Relevant subject headings include: CLIMATIC CHANGES, GLOBAL WARMING and GREENHOUSE EFFECT.

Available on CD-ROM.

JOURNALS

While articles on global warming, the greenhouse effect, and climatic change appear in many periodicals, those listed below regularly publish articles or summarize important developments on these subjects.

Atmospheric Environment. New York: Pergamon Press

Bulletin of the American Meteorological Society. Boston: American Meteorological Society.

Climate Dynamics. New York: Springer-Verlag.

Climate Research. Amelinghausen, Germany: Inter-Research.

Climatic Change. Dordrecht: Kluwer Academic.

EPA Journal. Washington, D.C.: U.S. Environmental Protection Agency.

Global and Planetary Change. New York: Elsevier.

Global Environmental Change. London: Butterworth-Heinemann Ltd.

Journal of Climate. Boston: American Meteorological Society.

Journal of Geophysical Research. Washington, D.C.: American Geophysical Union.

Journal of the Atmospheric Sciences. Boston: American Meteorological Society.

Natural History. New York: American Museum of Natural History.

Nature. London: Macmillan.

Science. Washington, D.C.: American Association for the Advancement of Science.

Scientific American. New York: Scientific American, Inc.

Theoretical and Applied Climatology. New York: Springer-Verlag.

WMO Bulletin. Geneva: World Meteorological Organization.

SELECTED ARTICLES

To help you begin your research, here is a list of representative articles on various aspects of global warming and climatic change.

Adams, R. M. and T. D. Crocker. The Agricultural Economics of Environmental Change: Some Lessons From Air Pollution. *Journal of Environmental Management*, v.28, n.4, p. 295-307, 1989.

Allen, R. G., F. N. Gichuki and C. Rosenzweig. CO_2-Induced Climatic Changes and Irrigation-Water Requirements. *Journal of Water Resources Planning and Management*, v. 117, n.2, p. 157-178, 1991.

Ausubel, J. H. A Second Look at the Impacts of Climate Change. *American Scientist*, v. 79, n.3, p. 210-221, 1991.

Barbier, E. B. The Global Greenhouse Effect: Economic Impacts and Policy Considerations. *Natural Resources Forum*, v.13, n.1, p.20-32, 1989.

Bazzaz, Fakhri A. and Eric D. Fajer. Plant Life in a CO_2-Rich World. *Scientific American,* p. 68-74, January 1992.

Broecker, Wallace S. Global Warming on Trial. *Natural History*, p. 6-14, April 1992.

Clark, W. C. et al. Managing Planet Earth (11 papers). *Scientific American*, v. 261, n.3, p.19-120, 1989

Cline, William R. Scientific Basis for the Greenhouse Effect. *Economic Journal*, v.101, p.904-21, 1991.

Cohen, Stewart J. Bringing the Global Warming Issue Closer to Home: the Challenge of Regional Impact Studies. *Bulletin of the American Meteorological Society*, v. 71, n.4, p. 520-526, 1990.

Cohn, J. P. Gauging the Biological Impacts of the Greenhouse Effect. *BioScience*, v.39, p.3, p.142-146, 1989.

Crowley, T. J. Are There Any Satisfactory Geologic Analogs for a Future Greenhouse Warming? *Journal of Climate*, v.3, n. 11, p. 1282-92, 1990.

Dickinson, Robert E. Uncertainties of Estimates of Climatic Change: A Review. *Climatic Change*, v.15, n.1/2, p.5-13, 1989.

Evans, Gary R. Agriculture, Forestry, and Food Security in Relation to Global Change. *MTS Journal*, v. 25, n.4, p.30-37, 1992.

Fisher, Donald A. et al. Model Calculations of the Relative Effects of CFCs and Their Replacements on Global Warming. *Nature*, v.344, p.513-516, 1990.

Fleagle, Robert G. The U.S. Government Response to Global Change: Analysis and Appraisal. *Climatic Change*, v.20, n.1, p. 57-81, 1992.

Fusonie, Alan and William Hauser. Climate History at the National Agricultural Library. *Agricultural History*, v.63, n.2, p.36-50, 1989.

Glantz, M. H. The Use of Analogies in Forecasting Ecological and Societal Responses in Global Warming, *Environment*, v.33, n.5, p.10-15, 27-33, 1991.

Gleick, Peter H. The Implications of Global Climatic Changes for International Security. *Climatic Change*, v.15 n.1/2, p.309-335, 1989.

Global Change and the Biosphere. (6 articles). *Annals of Botany*, v. 63, suppl. 1, 1991.

Gribbin, John R. Climate and Ozone: the Stratospheric Link. *Ecologist*, v.21, n.3, p. 133-135, 1991.

Hammond, Allen L., Eric Rodenburg and William R. Moomaw. Calculating National Accountability for Climate Change. *Environment*, v.33, n.1, p.10-15, 33-35, 1991.

Hansen, J. et al. Global Climate Changes as Forecast by Goddard Institute for Space Studies: Three-Dimensional Model. *Journal of Geophysical Research*, v.93, n.D8, p.9341-9364, 1988.

Hanson, K., T. R. Karl and G. A. Maul. Are Atmospheric Greenhouse Effects Apparent in the Climatic Record of the Contiguous United States (1895-1987). *Geophysical Research Letters*, v.16, n.1, p.49-52, 1989.

Horgan, John. Vapor Trail; Observations Support a Key Aspect of Warming Forecasts. *Scientific American*, v.262, p.24-25, 1990.

Houghton, R. A. and G. M. Woodwell. Global Climatic Change. *Scientific American*, v.260, n.4, p.36-44, 1989.

Idso, S. B. CO_2/Trace Gas Greenhouse Effect: Theory Versus Reality. *Theoretical and Applied Climatology*, v.38, n.1, p.55-56, 1987.

Jasani, Bhupendra. Monitoring the Greenhouse Effect From Space. *Space Policy*, v.5, p.94-98, 1989.

Karl, T. R., R. R. Heim, Jr. and R. G. Quayle. The Greenhouse Effect in Central North America: If Not Now, When? *Science*, v. 251, n.4997, p. 1058-61, 1991.

Krupa, S. V. and R. N. Kickert. The Greenhouse Effect: Impacts of Ultraviolet-B (UV-B) Radiation, Carbon Dioxide (CO_2), and Ozone (O_3) on Vegetation. *Environmental Pollution*, v.61, n.4, p.263-393, 1989.

Lashof, Daniel A. The Dynamic Greenhouse: Feedback Processes That May Influence Future Concentrations of Atmospheric Trace Gases and Climatic Change. *Climatic Change*, v.14, p.213-42, 1989.

Lashof, Daniel A. and Philip R. Ahuja. Relative Contributions of Greenhouse Gas Emissions to Global Warming. *Nature*, v.344, p.508-512, 1990.

Lindzen, Richard S. Some Coolness Concerning Global Warming. *Bulletin of the American Meteorological Society*, v.71, n.3, p.288-299, 1990.

Maddock, L. Effects of Simple Environmental Feedback on Some Population Models. *Tellus. Series B: Chemical and Physical Meteorology*, v. 43, n.3, p. 331-337, 1991.

Michaels, P. J. The Greenhouse Effect and Global Change: Review and Reappraisal. *International Journal of Environmental Studies*, v. 36, n.1/2, p.55-71, 1990.

Mintzer, I. M. Living in a Warmer World: Challenges for Policy Analysis and Management. *Journal of Policy Analysis and Management*,v.7, n.3, p.445-459, 1988.

Myers, Norman, guest editor. Tropical Forests and Climate (28 articles). *Climatic Change*, Special Issue, v. 19, n.1/2, 1991.

Oerlemans, Johannes. A Projection of Future Sea Level. *Climatic Change*, v.15, n.1/2, p. 151-174, 1989.

Oppenheimer, Michael. Climate Change and Environmental Pollution: Physical and Biological Interactions. *Climatic Change*, v.15, n.1/2, p.255-270, 1989.

Pastor, John and W. M. Post. Response of Northern Forests to CO_2-induced Climate Change. *Nature*, v.334, p.55-58, 1988.

Perrine, Richard L. and Derek C. Montague. Global Climate Change: What Revisions to Environmental Assessment Processes Will Mitigating Strategies Require? *The Environmental Professional*, v. 13, p. 125-138, 1991.

Ramanathan, V. Trace Gas Trends and Their Potential Role in Climate Change. *Journal of Geophysical Research*, v.90, p.5547-5566, 1985.

Rind, David, R. Goldberg and R. Ruedy. Change in Climate Variability in the 21st Century. *Climatic Change*, v.14, n.1, p.5-37, 1989.

Rosswall, T. Greenhouse Gases and Global Change: International Collaboration. *Environmental Science and Technology*, v.25, n.4, p. 567-573, 1991.

Scott, M. J., et al. Consequences of Climatic Change for the Human Environment. *Climate Research*, v.1, p.63-79, 1990.

Skolnikoff, Eugene B. The Policy Gridlock on Global Warming. *Foreign Policy*, p. 77, Summer 1990.

Special Issue on Global Warming (10 articles). *The Energy Journal*, v.12, n.1, 1991.

Strong, A. E. Greater Global Warming Revealed by Satellite-Derived Sea-Surface Temperature Trends. *Nature*, v.338, p.642-645, 1989.

Titus, J. G. Greenhouse Effect, Sea Level Rise, and Coastal Zone Management. *Coastal Zone Management Journal*, v.14, n.3, p.147-171, 1986.

Tonn, W. M. Climate Change and Fish Communities: A Conceptual Framework. *Transactions of the American Fisheries Society*, v. 119, n.2, p. 337-352, 1990.

Vellinga, Pier and Stephen P. Leatherman. Sea Level Rise, Consequences and Policies. *Climatic Change*, v.15, n.1/2, p.175-189, 1989.

Washington, Warren M. Where's the Heat? *Natural History*, v.99, p.66-72, 1990.

Washington, Warren M. and Gerald A. Meehl. Climate Sensitivity Due to Increased CO_2: Experiments with a Coupled Atmosphere and Ocean General Circulation Model. *Climate Dynamics*, v.4, n.1, p.1-38, 1989.

Weiss, Edith Brown. Climate Change, Intergenerational Equity and International Law: An Introductory Note. *Climatic Change*, v.15, n.1/2, p.327-335, 1989.

White, David C., Clinton J. Andrews and Nancy W. Stauffer. The New Team: Electricity Sources Without Carbon Dioxide. *Technology Review*, January 1992, p. 42-50.

White, Robert M. The Great Climate Debate. *Scientific American*, v.263, p.36-44, July 1990.

White, Robert M. Greenhouse Policy and Climate Uncertainty. *Bulletin of the American Meteorological Society*, v.70, p.1123-1127, 1989.

Wigley, T. M. L. and S. C. B. Raper. Natural Variability of the Climate System and Detection of the Greenhouse Effect. *Nature*, v.344, p.324-327, 1990.

Wood, Fred B. Monitoring Global Change: the Case of Greenhouse Warming. *Bulletin of the American Meteorological Society*, v.71, n.1, p.42-52, 1990.

Wuebbles, D. J., et al. The Role of Atmospheric Chemistry in Climate Change. *Journal of the Air and Waste Management Association*, v.39, n.1, p.22-28, 1989.

CONFERENCES, SEMINARS, SYMPOSIA, WORKSHOPS

Scientists frequently first present the results of their research at conferences, symposia, seminars or workshops. Proceedings of many such meetings are included in several of the indexing and abstracting services. Sources that provide subject indexing for proceedings only are listed here.

Bibliographic Guide to Conference Publications. 1975 - . Boston: G.K. Hall & Co.

Relevant subject headings include: CLIMATIC CHANGES; GLOBAL WARMING; GREENHOUSE EFFECT, ATMOSPHERIC.

Index of Conference Proceedings Received. 1973 - , no. 69 - . Boston Spa, West Yorkshire, U.K.: British Library. Document Supply Centre.

Relevant subject headings include: CLIMATIC CHANGES; GLOBAL WARMING and GREENHOUSE EFFECT.

Index to Scientific and Technical Proceedings. No. 1 - , Jan. 1978 - . Philadelphia: Institute for Scientific Information.

Relevant keywords include: CLIMATIC CHANGE; GLOBAL WARMING and GREENHOUSE EFFECT.

InterDok: Directory of Published Proceedings. Series SEMT - Science/Engineering/Medicine/Technology. V.3 - , Sept. 1967 - . Harrison, NY: InterDok Corporation.

Relevant keywords include: CLIMATE CHANGE; GLOBAL CHANGE; GLOBAL WARMING; and GREENHOUSE EFFECT.

Proceedings in Print. V.1 - , Oct. 1964 - . Halifax, MA: Proceedings in Print, Inc.

Relevant subject headings include: CLIMATE.

Selected Proceedings

Addison, P.A. Threats to a Healthy Forest by Air Pollution and Climate Change. In *Proceedings*. Society of American Foresters National Convention, 1989. Washington, D.C.: Society of American Foresters, 1989. pp.21-26.

Coping With Climate Change. Proceedings of the Second North American Conference on Preparing for Climate Change, a Cooperative Approach, December 6-8, 1988, Washington, D.C.; convened by The Climate Institute in cooperation with participating agencies and universities of the Canadian Climate Program. Washington, D.C.: Climate Institute, 1989. 696 p.

Dunnette, David A. and Robert J. O'Brien, editors. *The Science of Global Change: The Impact of Human Activities on The Environment*. Washington, D. C.: 1992. ACS Symposium Series 483.

Jager, J. and H. L. Ferguson, editors. *Climate Change: Science, Impacts and Policy*. Proceedings of the Second World Climate Conference. New York: Cambridge University Press, 1991. 578 p.

Ozone Depletion, Greenhouse Gases, and Climate Change. Proceedings of a Joint Symposium by the Board on Atmospheric Sciences and Climate and the Committee on Global Change, Commission on Physical Sciences, Mathematics, and Resources, National Research Council. Washington, D.C.: National Academy Press, 1989. 122 p.

Pearman, G. I. *Greenhouse: Planning for Climate Change*. Papers of a conference held at Monash University, Melbourne, in 1987. New York: E.J. Brill, 1988. 752 p.

Preparing for Climate Change. Proceedings of the First North American Conference on Preparing for Climatic Change: a Cooperative Approach, 27-29 October, Washington, D.C. Rockville, MD: Government Institutes, 1988. 516 p.

Rosswall, Thomas; Robert G. Woodmansee; and Paul G. Risser, editors. *Scales and Global Change: Spatial and Temporal Variability in Biospheric and Geospheric Processes*. Proceedings of a Workshop on Spatial and Temporal Variability of Biospheric and Geospheric Processes: Research Needed to Determine Interactions with Global Environmental Change, 10/28-11/1/85, Saint Petersburg, Fla. sponsored by Environmental Studies Board of National Research Council, ICSU's Scientific Committee on Problems of the Environment, and ICSU's International Association for Ecology. New York: Wiley, 1988. 355 p. SCOPE Report 35.

Schlesinger, M. E., editor. *NATO Advanced Study Institute on Physically-Based Modeling and Simulation of Climate and Climatic Change* (1986: Erice, Italy), 2 vols. Dordrecht; Boston: Kluwer Academic, 1988. 1084 p. NATO ASI Series C: Mathematical and Physical Sciences v. 243.

Second Symposium on Global Change Studies, Jan. 14-18, 1991, New Orleans, La. *Preprints*. Boston: American Meteorological Society, 1991, 136 p.

Third Symposium on Global Change Studies, January 5-10, 1992, Atlanta, Georgia. *Preprints*. Boston: American Meteorological Society, 1992.

Trabalka, John Richard and D. E. Reichle, editors. *The Changing Carbon Cycle: a Global Analysis*. Proceedings of the 6th Oak Ridge National Laboratory Life Sciences Symposium, Knoxville, Tennessee, 1983. New York: Springer-Verlag, 1986. 592 p.

GOVERNMENT PUBLICATIONS

Indexes and Abstracts

The following indexes provide access to thousands of reports published by the United States government. These indexes are also available as online databases and two are available on CD-ROM. Many of the reports are available in the more than 1,400 libraries that participate in the Federal Depository Program. Most can be borrowed through your local library's interlibrary loan service. Most can also be purchased from either the Government Printing Office or the National Technical Information Service. Please consult a librarian for assistance and additional information.

Energy Research Abstracts. July 1975 - . Oak Ridge, TN: United States Department of Energy, Office of Scientific and Technical Information.

Relevant subject headings include: CLIMATES; CARBON DIOXIDE--ENVIRONMENTAL IMPACTS; GREENHOUSE EFFECT and NITROUS OXIDE.

Government Reports, Announcements & Index. V.75, n.7 - , April 4, 1975 - . Springfield, VA: National Technical Information Service.

Relevant subject headings include: CLIMATIC CHANGES and GREENHOUSE EFFECT.

Available on CD-ROM.

Monthly Catalog of United States Government Publications. no.1 - , Jan. 1895 - . Washington, D.C.: United States Government Printing Office.

Relevant keywords include: CLIMATE CHANGE; CLIMATIC CHANGE; GLOBAL WARMING and GREENHOUSE EFFECT.

Available on CD-ROM.

Selected Government Publications

Agriculture, Forestry, and Global Climate Change--a Reader. Prepared by the Congressional Research Service, Library of Congress for the Committee on Agriculture, Nutrition, and Forestry, United States Senate. Washington, D.C.: U.S. Government Printing Office, 1989. 618 p. Y 4.Ag 8/3:S.prt.101-26

Changing by Degrees: Steps To Reduce Greenhouse Gases. Washington, D.C.: United States. Congress. Office of Technology Assessment, 1991. 354 p. Y 3.T22/2:D36/3

Climate Surprises. Hearing before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred First Congress, first session, on possible climate surprises--predicting greenhouse warming, May 8, 1989. Washington, D.C.: U.S. Government Printing Office, 1989. 152 p.
Y 4.C 73/7:S.hrg.101-128

Decker, Wayne L.; Vernon K. Jones; and Rao Achutuni. *The Impact of Climate Change From Increased Atmospheric Carbon Dioxide on American Agriculture*. Washington, D.C.: Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division, 1986. 100 p. DOE/NBB-0077

Dilemma of Fossil Fuel Use and Global Climate Change. Springfield, VA: National Technical Information Service, 1991. 25 p. DE91007859; CONF9104027.

DOE's National Energy Plan and Global Warming. Hearing before the Committee on Energy and Natural Resources, United States Senate, One Hundred First Congress, first session ... July 26, 1989. Washington, D.C.: U.S. Government Printing Office, 1989. 155 p.
Y 4.En 2:S.hrg.101-235

Energy Policy Implications of Global Warming. Hearings before the Subcommittee on Energy and Power of the Committee on Energy and Commerce, House of Representatives, One Hundredth Congress, second session, July 7 and September 22, 1988. Washington, D.C.: U.S. Government Printing Office, 1989. 265 p. Y 4.En 2/3:100-229

EPA's Global Climate Change Program: Global Landfill Methane. Springfield, VA: National Technical Information Service, 1991. PB91223230

Global Change--What You Can Do: Hearing before the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred First Congress, second session on ... April 25, 1990. Washington, D.C.: Government Printing Office, 1991. 85 p.
Y 4.C73/7:S.hrg.101-1160

Global Warming and Other Environmental Consequences of Energy Strategies: Hearing before the Subcommittee on Environmental Protection of the Committee on Environment and Public Works, United States Senate, One Hundred Second Congress, first session, March 13, 20, and April 26, 1991. Washington, D.C.: Government Printing Office, 1991. 332 p.
Y 4.P96/10:S.hrg.102-101

Global Warming Mitigation of Three Tree Plantation Scenarios, Final Report, September 1989-June 1990. Springfield, VA: National Technical Information Service, 1991. 68 p. PB91159608

Implications of Global Warming for Natural Resources. Oversight hearings before the Subcommittee on Water and Power Resources of the Committee on Interior and Insular Affairs, House of Representatives, One Hundredth Congress, second session ... hearings held September 27, 1988: Washington, D.C.; October 17, 1988: San Francisco, CA. Washington, D.C.: U.S. Government Printing Office, 1989. 668 p. Y 4.In8/14:100-58

Lashof, Daniel A. and Dennis A. Tirpak. *Policy Options for Stabilizing Global Climate*. Draft, report to Congress. Washington, D.C.: U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, 1989. EP 1.2:G51/2/draft/v.1-2,exec.sum.

Moss, Marshall E. and Harry F. Lins. *Water Resources in the Twenty-First Century; a Study of the Implications of Climate Uncertainty*. Reston, VA: Department of the Interior, U.S. Geological Survey, 1989. 25 p. Circular 1030. I 19.4/2:1030

Neilson, R. P. et al. *Sensitivity of Ecological Landscapes and Regions to Global Climatic Change*. Washington, D.C.: Department of Energy, 1989. EPA 600/3-89-073

Our Changing Planet: The FY 1992 U.S. Global Change Research Program. A Report by the Committee on Earth and Environmental Sciences. A Supplement to the U. S. President's Fiscal year 1992 Budget. Washington, D.C.: Federal Coordinating Council for Science, Engineering and Technology, Committee on Earth and Environmental Sciences, 1991. 102 p. PB91145805

Policy Implications of Greenhouse Warming: Hearing before the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred Second Congress, first session, April 25, 1991. Washington, D.C.: Government Printing Office, 1991. 73 p. Y4.C73/7:S.hrg.102-259

Ten Key Questions Indicating the Level of Current Uncertainty in Forecasting Climatic Change. Springfield, VA: National Technical Information Service, 1991. 26 p. DE91010124; UCRLID106243

Titus, J. G., editor. *Greenhouse Effect, Sea Level Rise and Coastal Wetlands*. Washington, D.C.: U.S. Environmental Protection Agency, 1988. 159 p. PB89203665

U. S. Efforts to Address Global Climate Change: A Report to Congress. Prepared jointly by the U. S. Department of State and the U. S. Environmental Protection Agency. Washington, D.C.: U. S. Environmental Protection Agency, 1991.

Worrest, R. C.; K. D. Smythe; and A. M. Tait. *Linkages Between Climate Change and Stratospheric Ozone Depletion*. Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development, 1989. 124 p. PB90112590

A Second Look at the Impacts of Climate Change

We may be worrying too much about crops, coastlines and quick action—but too little about water, wildlife and gaps in information

Jesse H. Ausubel

Hypothesis 1: Faster change is worse.

Jesse H. Ausubel is a Fellow in Science and Public Policy at the Rockefeller University and Director of Studies for the Carnegie Commission on Science, Technology and Government. This article is adapted from a background paper he contributed to Policy Implications of Greenhouse Warming, *published in April by the National Academy [illegible] Mr. Ausubel received his bachelor's degree from Harvard University and master's degrees in management and international affairs from Columbia University. He was the National Research Council staff officer responsible for* Changing Climate, *the first comprehensive study of the greenhouse effect, published in 1983. Address: The Rockefeller University, 1230 York Avenue, New York, NY 10021-6399.*

With the passage of time, a picture of an issue tends to settle into the public mind. A few images and sound bites come to monopolize our thinking. Now that the "greenhouse effect" issue has been prominent in the news media for a few years, such a collection of ideas has started to form—a shared set of images and concerns about life on a warmer earth. The dominant images are probably those of parched crops and flooded coastlines. The best-remembered phrase may be "the next most serious threat after nuclear war," from the declaration of the International Conference on the Changing Atmosphere in 1987.

To what extent do such widely held ideas and impressions match the current state of knowledge about the human impacts of global climate change? This question deserves close examination. As we consider new public policies and large economic investments, it is important to recognize the picture on which society is implicitly relying for its decision-making. It is also important to examine closely the common wisdom, to understand gaps, weaknesses and contradictions in the picture, and to consider how the picture might improve.

As part of the recent study on policy implications of global warming conducted by the National Academies of Sciences and Engineering, I was asked last year to join in such an examination. In an effort to summarize popular perceptions of the human impacts of global warming, I scanned magazine and newspaper articles and records of Congressional hearings, and looked at visual material ranging from book covers and cartoons to educational video tapes. I noticed that certain themes were sounded with confidence again and again, and that eight hypotheses seemed to form the core of the conventional wisdom. The eight hypotheses are:

1. Faster change is worse.
2. Waiting to make policy and to take action will drive up the costs of response.
3. There are only losers from climatic change.
4. The most important impacts will be on agriculture and from sea level rise.
5. Changes in extremes will be more important than changes in means.
6. The changes envisioned are unprecedented.
7. Impacts will be worse on less-developed countries than on developed countries.
8. There are hedging strategies that are clearly economical.

In this article, I shall make an effort to test these hypotheses against research findings from the literature about the impacts of climate change, which has burgeoned since the late 1970s. As with any group of hypotheses, some hold up better than others on close inspection; a few appear to bear little relation to what evidence has been gathered. I would like to offer, therefore, a revised set of statements and some thoughts about the directions for future research and policy debate that are suggested by this exercise.

1. Is Faster Change Worse?

One of the most common statements made about the consequences of global warming is that they will necessarily be severe because of the unusually rapid pace at which warming is expected to proceed. An increase of 3 degrees Celsius in the annual average temperature over 50 years is seen as more threatening than a 3-degree warming that takes place over 75 years.

The research usually cited to demonstrate the importance of rates of change has to do with the migration of trees. The essential point is that in a scenario of rapid warming, trees will not be able to move as fast as the climate. The power and relevance of this example must be assessed in the context of the numerous changes likely to occur over the given time frame. Each recent century has brought massive land and ecosystem transformations. In past centuries the major forces

were the spread of agriculture and the growth of cities, rather than climatic shifts.

We must ask how likely it is that during the next 100 years climatic change will match or exceed other forces—gypsy moths, spruce budworms, vacation homes—as a transforming factor for ecosystems. Rapid change in climate may be exceeded in importance for forests by changes in soil dynamics, acidification, seed sources and the direct effects of trace gases, air pollution and forest-management strategies—not to mention the markets for wood products.

This ecological example illustrates that for both natural and built systems, one must assess the importance of the rate of climatic change by comparing it with the rates at which the systems that might be affected change and adapt. We can ask, for instance: How frequently does industry acquire new capital stock, and how often does agriculture adopt new equipment and seeds to adjust to changing conditions? How quickly is the stock of residential and industrial buildings replaced and renovated? How quickly are water supply systems and dikes constructed and renewed? Surveying these rates suggests that in most cases they are rapid in relation to the projected climatic change.

It is also important to ask to what extent it is possible to separate the rate of change from the direction of change. If the forecast is for a greening of the Sahara Desert, many Africans in the regions affected would probably *prefer* that the increase in rainfall occur over 20 to 30 years rather than over 50 to 100 years. Without some notion of the direction of change, then, rates themselves may not matter much, except in an extreme scenario. In such a scenario, the climate is changing like a spinning carnival ride, and the sensations are equally disorienting whether traveling clockwise or counterclockwise. Short of such a scenario, one has to ask, "What is fast?" and look for thresholds at which rates clearly begin to be important. Would consequences differ perceptibly if the rate of change globally is, say, 0.3 degree Celsius per decade rather than 0.2 degree per decade?

In the end, the critical question for societies and their economies may be whether the climatic change is expected, rather than how rapid it is. Fast change that is anticipated may matter less than slower change that is unforeseen. The specific shape of the transition may also matter more than the rate averaged over decades. A steady, linear movement that after 50 years leaves the climate warmer by 3 degrees Celsius may be less problematic than a jagged, irregular movement to a climate warmer by 2 degrees, since in the former case conditions can be better anticipated.

2. Must We Act Now?

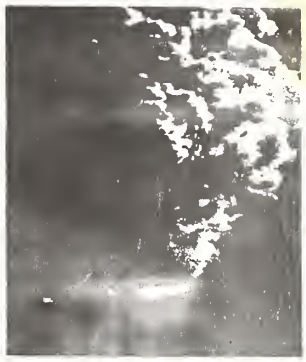
Those who advocate putting off actions that are proposed in anticipation of global climatic change often hear that waiting will make the costs of response higher. This position is grounded in pessimism about future technology, future economic resources and the ability to acquire new information.

Several lines of evidence argue against this pessimistic assumption. First, the menu of response options may increase through innovations, technological and otherwise. If it were decided today that societies should immediately reduce their greenhouse-gas emissions by 20 percent, several countries might achieve this reduction by building light-water nuclear reactors. Such investment would further lock these societies in to energy technologies that may be inferior to alternatives, nuclear or non-nuclear, that will be available fairly soon. In short, it is not clear that it is better for the United States to spend, say, $100 billion during the next five years on nuclear and alternative energy technologies to reduce carbon dioxide emissions than to wait and spend the equivalent amount during a future period.

In fact, if there is economic growth in the intervening period, the available and spendable resources should increase. It may then be possible to select choices from the menu that are now excluded because of high cost. In other words, if a future society is wealthier than today's, it may be able to finance highly attractive response options that are unaffordable at present; these options might render superfluous the clumsy interventions that now dominate the set of feasible choices. In the U.S. Environmental Protection Agency's scenario of unimpeded growth in the emission of greenhouse gases, annual per capita global income in the year 2100 is projected to be $35,600. Per capita income in the United States would be $150,000 or more, if current income ratios hold. Such flows of wealth open wide vistas for adaptation to climate change, as well as for expenditures to reduce greenhouse-gas concentrations.

When we shift our perspective away from the world's centers of prosperity, the decisions are different but the conclusions not necessarily so. For parts of the world such as Africa, many urgent questions of immediate survival and economic development must be faced. In these regions it is important to analyze carefully whether now is the proper time to begin allocating resources in anticipation of the uncertain impacts of global warming. And in the U. S. S. R. and the nations of Eastern Europe, the optimal timing of greenhouse investments must be explored in light of the urgent need to put in place better private and governmental decision-making processes.

The argument about timing is also depen-



Hypothesis 2: Waiting to make policy and to take action will drive up the costs of response.

dent on the quality of the information now in hand and the probability that it will improve. There are areas in which we have reason to be optimistic that we will have, as time goes on, information useful in making measured responses to the challenge of climatic change. New information could, for example, allow us to better assess the likelihood of various amounts of sea-level rise and thus guide resources more efficiently into a variety of adaptive responses. In the case of large, lumpy investments such as those needed to protect coastal regions from flooding and seawater intrusion or to transfer water between river basins, it is not apparent that the quality of current forecasts is sufficient to trigger action.

There may, however, be actions that are more easily and effectively taken now, or soon. As the world becomes more crowded with people, it is likely to become more difficult to reserve land for corridors that would allow the migration of plants and animals as climate shifts. In some regions, such as coastal zones and floodplains, waiting may further set society into patterns that increase vulnerability and reduce flexibility. A parallel argument applies to the use of fossil fuels: The further they are allowed to penetrate into the fabric of society, the larger becomes the job of substituting for them.

In summary, if society becomes better supplied with tools, money and knowledge, the menu of options for adaptation will be superior in the future—far superior, if the technological and economic progress of the past 100 years continues apace. Because information is easier to transfer than are wealth and technology, it is especially important to acquire better information as quickly as possible. A stitch in time saves nine *if* you know how to make the right stitch. It is quite possible that the optimal present strategy on the greenhouse issue, for many nations, is a continued emphasis on increasing the information available and improving its quality.

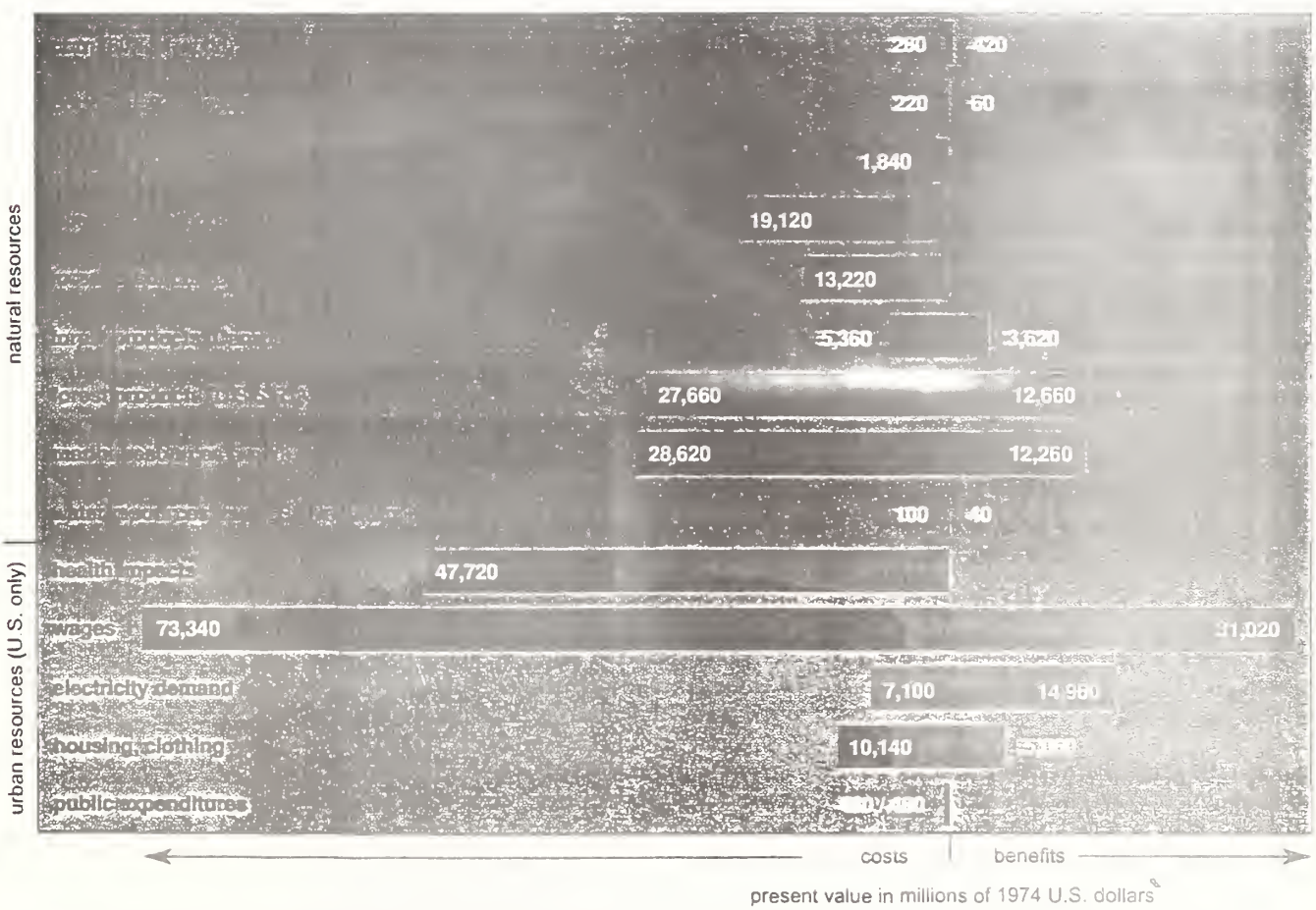


Figure 1. Economic costs of global cooling might far exceed those of global warming. A study of the costs of atmospheric cooling undertaken by the U. S. Department of Transportation in the early 1970s found that a decrease in average temperature of 1 degree Celsius would be costly, but that a warming of 0.5 degree Celsius would produce net economic benefits. The study noted that medical expenditures, mortality and wages all seemed to increase with cooler temperatures. Activities related to forest products and to marine resources were expected to benefit from warming. The effects of warming on wheat, rice, U. S. forest products and health were not estimated. Blue bars show estimated effects of cooling; red bars are effects of warming. Equivalent impacts on U.S. public expenditures were expected to result from either cooling or warming (*purple bar*). Information in parentheses describes the areas covered by the study. (Data from CIAP 1975.)

3. Will We All Be Losers?

The contention that there will be no winners from global warming seems to rest on three arguments. One is the risk of a shift to a calamitous climate, in which warming would reach a catastrophic extreme—a hot climate as extreme as the cold one experienced 18,000 years ago, when the average temperature was cooler by 5 degrees Celsius and an ice sheet buried North America. A second argument emphasizes the accumulation of global problems. The third is based on the perception that society is becoming increasingly brittle.

The first argument emphasizes the non-negligible probability that climatic change will follow a catastrophic course, in which case the "everybody loses" statement is—tautologically—true. This could occur if greenhouse-gas emissions are extremely high, if atmospheric concentrations reach very high levels, and if the expected warming follows. A scenario of even greater concern is that of a "runaway" greenhouse effect, in which a relatively small change in concentrations triggers an unexpectedly large change in the climate system. Such a scenario is physically possible, but so far is not supported by much more than highly conjectural assertions. One set of interesting conjectures relates to shifts in ocean currents, which appear to have occurred quite rapidly and unaccountably in the past. Another relates to warming in high latitudes; this might release large amounts of methane from clathrates in the tundra and continental margins, thereby greatly increasing greenhouse-gas concentrations in the atmosphere. It might be useful to survey experts to ascertain what they think is the probability of such a scenario: 1 in 10, in 100, in 1000? Contingency plans must be developed for high-consequence, low-probability scenarios, just as contingency plans are made for earthquakes, reactor failures and threats of nuclear war.

The second argument for the "everybody loses" hypothesis is that environmental change will cause extreme and comprehensive destabilization of social and economic conditions worldwide. Like the runaway greenhouse effect argument, this is plausible but entirely conjectural. A scenario has yet to be worked out in detail, beyond popularizations. The essence of the view is that almost everything in the world is going wrong—that all the indicators about population, food, terrorism, radiation and the ozone layer, for example, are moving ominously. The overall system is heading for catastrophe, and climate is part and parcel of this. Climatic changes will add stress by reducing the reliability with which a population of 10 billion can be fed and by adding to the number of refugees as a result of rising seas. In this view, the amount of climatic change matters, with larger being worse, but even a small change could be bad—the straw that breaks the camel's back.

A variation on this argument holds that sociotechnical systems are becoming more brittle. Although for many specific contingencies societies may be insulating themselves successfully from climatic change, this protection comes through increasingly elaborate systems that are more vulnerable to catastrophe from both natural and social hazards that may occur infrequently. In the open and enlarging world system of today, vulnerability may be shared ever more

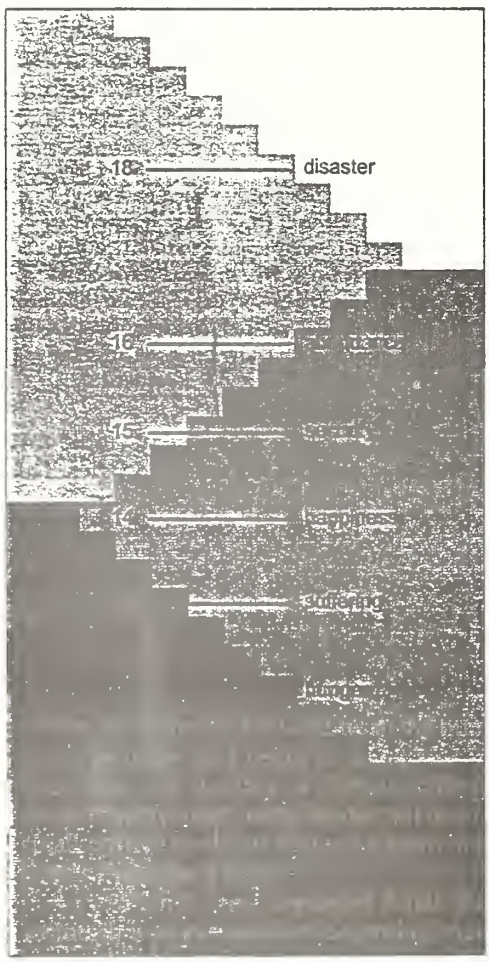
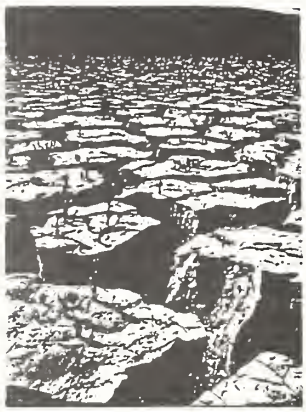


Figure 2. Nilometers of ancient Egypt measured the annual spring flood of the River Nile, which determined the success of the following growing season. This scale shows the interpretation of nilometer readings (in cubits) that was in use during the time of the Roman scholar Pliny (AD 23–79). From hard experience, the Egyptians knew that disaster—catastrophic flooding that could destroy their canals and dikes—impended just above the ideal river level (Heathcote 1985). Some would suggest that the current annual average temperature of the earth, 16 degrees Celsius, similarly places society not far below climatic disaster.



Hypothesis 3: There are only losers from climatic change.

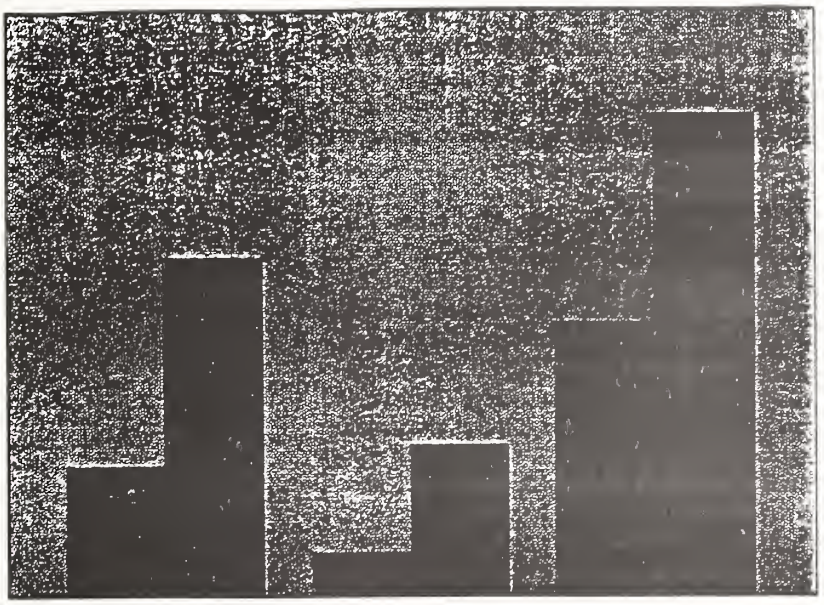


Figure 3. Heat waves are a worrisome probable consequence of an increase in global temperature. According to one estimate, the odds of having a heat wave in a given year could double or triple in some major cities if the average temperature increased by 3 degrees Celsius, with no increase in temperature variability. Bars show the annual probability of a heat wave, defined as five or more consecutive days on which the high temperature exceeds a threshold—95 degrees Fahrenheit for Washington and Des Moines, 100 degrees for Dallas. Pale-red bars represent the odds of a heat wave without a warming; bright-red bars show the odds after the increase in average temperature. (Data from Mearns, Katz and Schneider 1984.)

widely, and consequences may ripple into previously unrelated areas or societies. This argument is comparable to concerns about electricity blackouts, the implications of which multiply with our growing dependence on a reliable power supply. In this perspective, even small climatic changes could trigger collapse of social and physical structures.

Balanced against arguments that any climatic change is bad or extremely risky for everyone is specific research showing that there could be winners from climatic change. This proposition seems logical. The present climate of the earth is harsh in many, if not most, parts of the globe. It is easy to imagine that several, even many, regions will find themselves in more favorable conditions—milder winters, more abundant rainfall—as climate warms. One study suggests that there may be an increase of from 3 to 11 percent in global mean precipitation.

Indeed, there is a growing body of literature showing, based on analyses of the widely cited results of general-circulation models, that there would be benefits from global climate change. For example, on the basis of detailed studies of Japanese agriculture, Masatoshi Yoshino and his colleagues concluded in 1988 that in Japan, scenarios based on a doubling of atmospheric carbon dioxide levels "would, *ceteris paribus*, result in an enormous rice surplus." This conclusion is based on analyses of rice yields relative to the long-term baseline productivity for a "dumb farmer," that is, one who takes no adaptive steps but goes about his business in the climate brought about by doubled CO_2 in the atmosphere as if it were the climate of today. Yoshino's group noted that most of their estimates reflected a poor response for a well-managed commercial crop. The surplus would be even greater if farmers were, as is probable, to adapt their cultivation methods to the new climate by actions such as introducing more heat-loving rice varieties with earlier planting dates. Such adjustments might result in increases of rice yields in areas of Japan of up to 25 percent, relative to recent levels. A similar case study showed that major national surpluses of food grains can also be expected in Finland.

It is also worth noting that migration trends suggest that many people seem to prefer a warmer climate. Within the United States, the migration toward the Sunbelt has been widely analyzed. To a large extent this is a climate-induced migration; people even accept lower wages to live in warmer climates. A similar phenomenon has occurred in Canada. The behavior of populations over the past few decades thus suggests that many people might feel themselves winners to have a warmer climate, other things being equal or nearly so.

Finally, there is also the curious fact that previous, detailed studies showed that on balance, global cooling would be adverse and global warming beneficial. These studies, undertaken as part of the Climate Impact Assessment Program (CIAP) of the U.S. Department of Transportation in the early 1970s, were primarily concerned with the possibility of global cooling that might be associated with a large fleet of supersonic transport planes operating in the stratosphere. The warming scenarios were explored partly as a reference point. As Figure 1 shows, both warming and cooling produced a blend of benefits and costs. Global-cooling scenarios produced net costs, whereas moderate global-warming scenarios tended to produce net benefits. Studies combining warming and cooling scenarios with both increases and decreases in precipitation yielded essentially the same result, with a warmer and wetter scenario the most favorable. The numbers suggest a logical conclusion: that there are both winners and losers with any gradual climate change.

(The Japanese and Finnish studies take account of an important additional fact: that carbon dioxide is food for plants. Holding other conditions steady, doubling the CO_2

content of the atmosphere appears likely to increase yields by somewhere between 10 and 50 percent.)

It is tempting to speculate that analyses of any potential climatic change—whether cooling in the early 1970s or warming for the past decade—are somehow biased by a sense of threat. Alternatively, it is possible to argue that human societies are now precariously balanced from a socioeconomic viewpoint at a climatic optimum, reminiscent of the gradations used by the ancient Egyptians to interpret the readings on their nilometers (*Figure 2*), which measured the height of the Nile River. It is true that either a vast expansion of glaciers or Venusian heat would render human habitation of earth more difficult, very miserable, and perhaps impossible. But no convincing evidence exists to replace the stone markings used by the Pharaohs to measure the height of the Nile with measures of annual average global temperature. By coincidence, the number 16—the river level signifying "abundance," located not far below disaster—is about the current number for global average temperature, in degrees Celsius.

There are also losers from a scenario in which limitations are placed on emissions of greenhouse gases. In this case the losers are the individuals, groups or nations whose economic development is slowed because of higher energy prices or other barriers to access and use of carbon (or of other resources related to emissions of greenhouse gases). The losers also would include the carbon-rich nations whose resource, in or on the ground, is devalued by restrictions on carbon use. In fact, the biggest economic losers from a reduction in CO_2 emissions might be the less-developed countries and the oil-exporting countries. Carbon is the largest export of the poor nations of the South to the rich nations of the North. If the industrialized nations continue to increase their energy efficiency and reduce reliance on hydrocarbons, markets dry up for Mexico, Venezuela, Ecuador, Gabon, Nigeria and Indonesia. Carbon is also by far the largest export of the U.S.S.R.

Finally, a discussion of winners and losers is incomplete without mention of the direct beneficiaries of the greenhouse issue—namely, those employed in research and negotiation about it. The "greenhouse industry" will employ at least several thousand scientists, lawyers, diplomats and others.

In summary, statements that there are no winners or are only losers from global warming appear biased, unless based strictly on an apocalyptic scenario. It seems more accurate to emphasize that there will be complex distributive issues involved in climatic change, with continually shifting sets of losers and beneficiaries, both from the changes in the climate and the regulation of economic activities that may be causing the climatic changes.

4. Which Impacts Should Worry Us Most?

There is by now a large literature on the impacts of climatic change on agriculture. The findings in the literature are not alarming, in large part because farmers are not dumb; they are accustomed to continually adapting to variations in markets and technology, as well as in environment and climate. For the most part, projected impacts of climate change on agriculture are small or moderate in comparison with impacts associated with fluctuations in government subsidies, international trade and other economic factors or with productivity gains that come with technological progress. Also, for a lengthening list of nations, agriculture is no longer the outdoor activity that is of most value. In nations such as the United Kingdom and Germany, agriculture is only about 3 percent of gross national product, so impacts of climate change on agriculture pose little threat to national income. Travel and recreation may prove to be sources of jobs and revenue that are more vulnerable to climatic change than agriculture in several regions.

Hypothesis 4: The most important impacts will be on agriculture and from sea level rise.

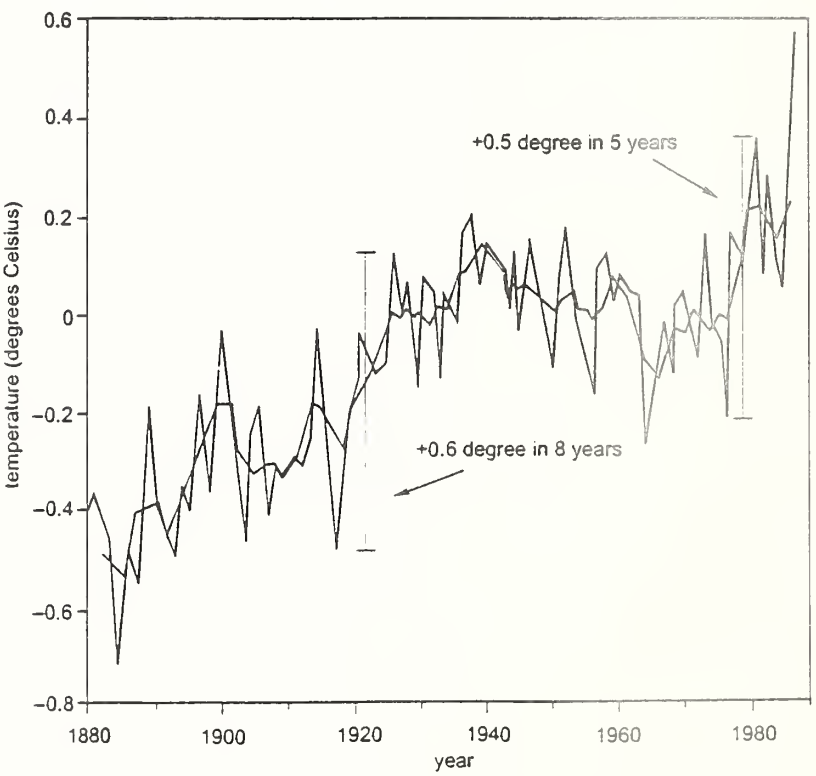


Figure 4. Significant global warming has been experienced during short periods since 1880. The record of annual average (*red*) and five-year average (*blue*) global temperatures shows that the earth's average temperature jumped 0.6 degree Celsius during the years 1918–1926, and 0.5 degree between 1976 and 1981—faster rates than are projected under current scenarios for global warming. (After Hansen and Lebedeff 1988.)

Hypothesis 5: Changes in extremes will be more important than changes in means.

The consequences of sea-level rise are on a grand scale indeed, if one uses scenarios in which the sea level rises several meters. A quarter of Florida might be flooded if the ocean were five meters higher. The probable sea-level rise over the next 100 years—the rise that would be associated with a global temperature increase of 3 or 4 degrees Celsius—is about 70 centimeters. Of this rise, 33 centimeters are expected by 2050. Impacts from such rises are a concern to be addressed, but hardly merit images of the Great Flood. The impacts of sea-level rise may be scarcely apparent at all for the next 30 to 40 years. The fascination with sea-level rise probably originates in the fact that it could be disastrous, but it is mistaken to conflate coastal inundation with the likely impacts during the next generation or two.

Agriculture and sea level have captured much of the popular attention, but a more serious concern may be water resources. A 1989 comprehensive study of climate and water in the United States by the Panel on Climate and Water of the American Association for the Advancement of Science shows that the prospect of climatic change lights warning lamps of vulnerability in several regions. Vulnerability depends on the ratio of water supply to demand, and climate can affect both quantities. In a region such as the Missouri River basin or California, where the balance is already delicate, even small changes could bring substantial stress.

Another sector that looks worrisome is conservation of nature. Although agriculture and economic activity may shift with climate, our natural heritage—exemplified by national parks such as the Terai in India, Serengeti in East Africa, and Yosemite and the Everglades in the United States—cannot. Changes in variables, such as fire, that affect ecosystems, and changes in the delicate balance that maintains systems such as wetlands could have regrettable consequences.

It is interesting also to note that among the highest costs of *cooling* found in the CIAP study (Figure 1) were losses of forest production and marine resources. Largest of all were the economic costs of impacts on health and of wages. The high estimates of costs of health impacts from cooling arose from findings that there is a covariation between several climate variables and expenditures for physicians' services. Mortality rates also were related to various measures of climate. The central hypothesis in the analysis of wage effects was that if the cost of living rises as one moves to different climatic regimes—as seems the usual case with a move to a cooler climate—then wage earners will have to be paid a differential to compensate for this difference.

In summary, the conventional wisdom seems to rely on preconceptions about which climatic impacts will be most serious. Many commentators and experts on global warming evidently ignore or disbelieve the results of the scholarly literature. The global-warming issue may provide cultural anthropologists with an interesting case study of the ways we protect paradigms and reject information that does not fit. There is definitely a need for more systematic, thorough studies worldwide of impacts, together with adaptation, from which it would be possible to identify the greatest vulnerabilities.

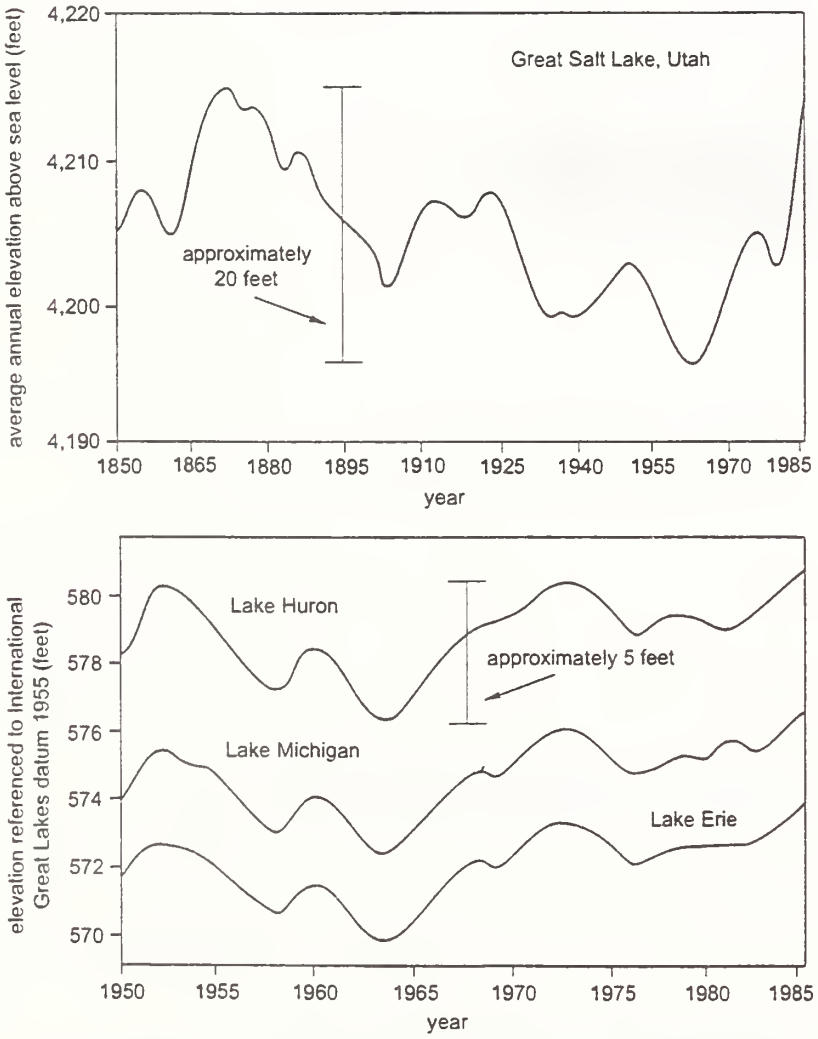


Figure 5. Levels of North America's great inland seas have exhibited large changes that may be analogous to the rises in sea level that are forecast as a result of global warming. The Great Salt Lake has fluctuated as much as 20 feet over the course of a century, and the levels of the Great Lakes have risen more than 3 feet within a decade. The shores of these lakes are developed for a range of uses similar to those of ocean coastlines. (Data from Arnow 1985 and Hitt and Miller 1986.)

5. The Importance of Extremes

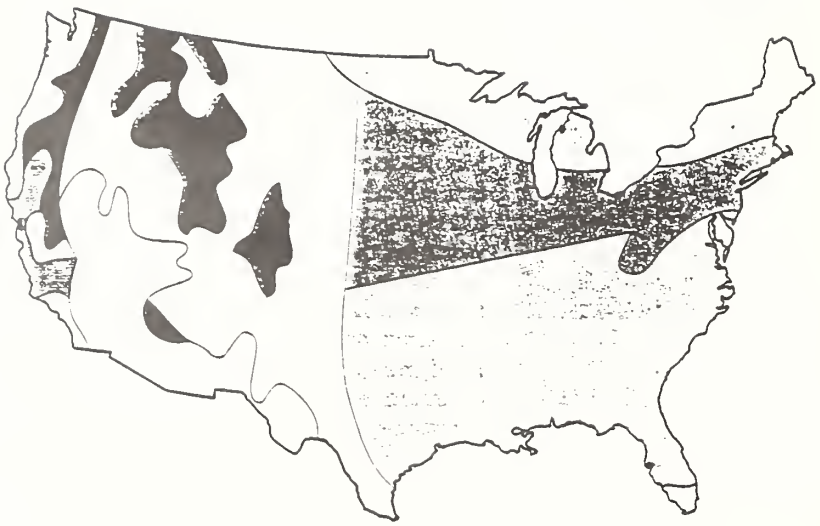
Statements made about climatic change are often based on the notion that what matters more is not the average behavior of the system, but its behavior at its limits, which may be masked in consideration of averages. Important changes in extremes, it is noted, might come about in either of two

ways. A shift in a climate mean (for instance, in the regional average spring temperature) could slide the complete intact distribution of climate events in such as way as to cross more frequently thresholds that are now rarely breached. Alternatively, the shape of the distribution of events might change in the direction of increased vulnerability.

So far, there are no more than a handful of papers in the scientific literature that directly examine changes in climatic extremes and their impacts. Linda Mearns, Richard Katz and Stephen Schneider in 1984 looked at the example of a change in the probability of extreme heat waves (five days or more in a row with a maximum temperature above a 95- or 100-degree Fahrenheit threshold). They examined what might happen in three U.S. locations if the mean temperature were to increase by 3 degrees Fahrenheit, while there were no changes in the standard deviation of daily maximum temperatures nor in the autocorrelation of daily temperature variations. The results are worrisome; the odds of extreme heat waves would double or triple in each city (Figure 3). It would be useful to carry out more exercises of this type, emphasizing thresholds that climatic variations may cross. In addition to heat-stress levels for crops, an obvious example of such a threshold is the melting of permafrost. It would also be useful to study whether there might be states of the climate system that would be characterized by more frequent and severe storms.

Will temperatures and precipitation become more variable with global warming? To the extent that there are research results touching on this question, they do not indicate an increase in variability. In fact, allowing for considerable noise in the results, they imply qualitatively that standard deviations of surface temperatures are more likely to decrease than to increase as a result of greenhouse warming. Precipitation variability, on the other hand, usually increases as climate warms. Of course, if the climate becomes drier on average, the chances of extremely dry weather are likely to increase, unless the rules of the system change.

In summary, we need to identify important thresholds and discontinuities, to study the likelihood that the altered natural system will reach these points, and to do more work about what consequences might, in fact, ensue. An "extreme," by itself, has little meaning. If summer temperatures in Siberia regularly breach 80 degrees Fahrenheit rather than 70 degrees, are there reasons to be concerned? Would, for example, large releases of biogenic gases be triggered from the soils?



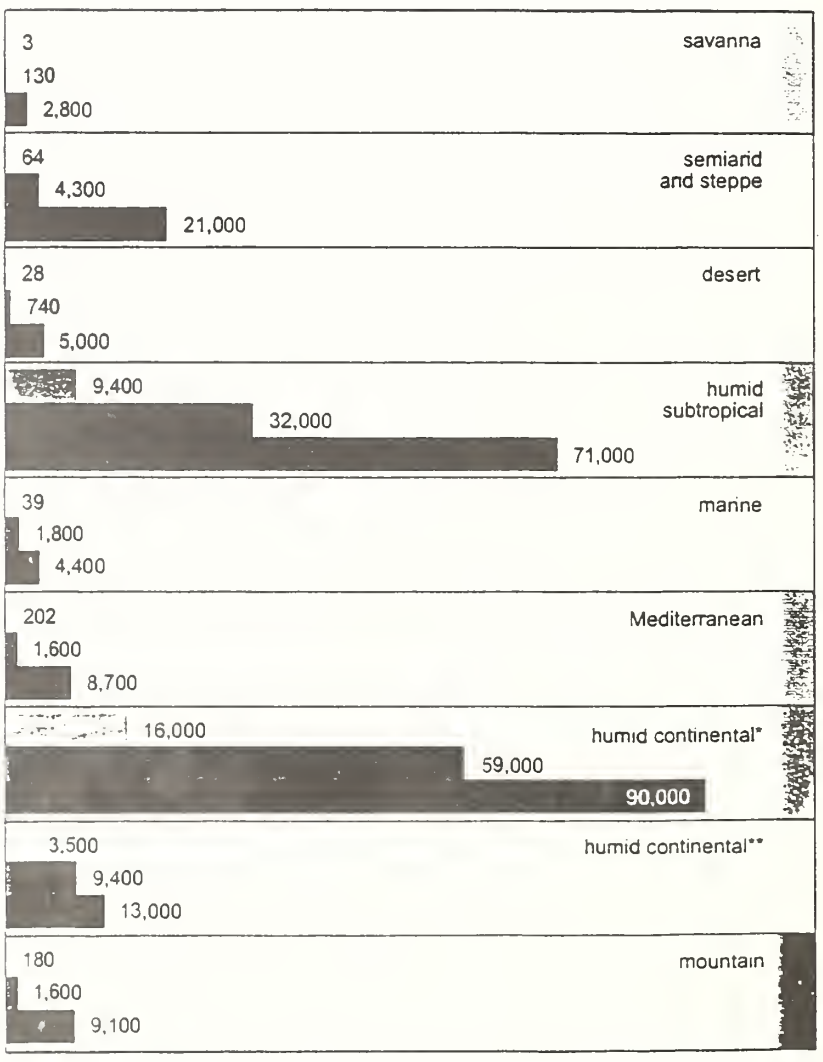


Figure 6. Climates once thought hostile have become popular human habitats with the aid of modern adaptations. In 1860 (*light gray bars*), less than 1 percent of the U.S. population lived in semiarid, desert or mountain regions. This figure rose to 6 percent in 1920 (*medium gray bars*). By 1980 (*dark gray bars*) the population in these climate zones had passed 35 million, or 15 percent of the total population. Large numbers of people now live in every type of climate. (Schelling 1983.)

Hypothesis 6: The changes envisioned are unprecedented.

6. Will the Changes Be Unprecedented? If one says that global warming will bring about unprecedented changes, one is saying that things are about to happen that have never happened before. Yet the climatic record includes evidence of numerous changes in the past that are comparable or analogous to current projections of global warming over the next century. For example, in the period 1952–1961 the summer climate of the northern and central Great Plains and Rockies in the United States was 0.9 to 1.5 degrees Celsius warmer and had 25 to 100 millimeters less rainfall on average than during the decade 1942–1951. In fact, the nature of climate variability is such that decadal fluctuations in average temperature (up to 1 degree Celsius annually or 2 degrees from one season to the same season the following year) and precipitation (approximately 10 percent annually) have occurred in most areas of the United States during the last 60 years. Raymond Bradley and his colleagues noted in *Science* in 1987 that analysis of precipitation data on a hemispheric basis has revealed important changes in climate that, apart from the well-known declines in North African rainfall, have gone generally unnoticed over the past decades.

There have been periods of rapid global as well as regional shifts. Although the overall record of the past 100 years appears to show a warming of only about 0.5 degree Celsius, during the eight years around 1920 the average temperature of the earth jumped 0.6 degree Celsius, and between 1976 and 1981 it jumped 0.5 degree (*Figure 4*). Thus, even the "upper" scenario of a warming rate of 0.8 degree Celsius per decade used in current studies would not appear to be far from the range of recent experience, at least over the short term. Note that no global climatic catastrophe was experienced either in the early 1920s or the late 1970s.

There are other ways in which analogies might be drawn. For example, there have been large changes in the levels of the Great Lakes and Great Salt Lake (*Figure 5*). The rises and falls of these inland seas—with shores developed for a range of uses, from airports to recreation, not different from ocean coastlines—have been as much as 5 feet for the Great Lakes and 20 feet for Great Salt Lake. These changes far exceed those forecast for the next century in association with global warming. There have also been cases of subsidence of coastal land, caused by pumping out of oil and gas resources in Louisiana and other regions, that are analogous with sea-level rise. Sea-level rises of 20 centimeters have been sustained over several months during an El Niño. The microclimates of cities have also warmed considerably. A recent comparison of summertime temperatures in Atlanta and a nearby rural weather station suggests that Atlanta's temperature increased between 1974 and 1988 by about 2 degrees Celsius as a result of urbanization and the concomitant intensification of the urban heat island.

As Thomas Schelling pointed out in a 1983 National Research Council report on changing climate, human movement also creates an equivalent of climatic change. If an individual boards an airplane in New York and disembarks in Los Angeles, he or she has undergone a climatic change much greater than that forecast as a result of global warming. Moreover, large numbers of people are now living in every type of climate, including those that were considered extremely inhospitable a century ago—especially the hotter and drier climates that are usually associated with anxiety about the greenhouse effect (*Figure 6*). It is hard to imagine what would be unprecedented unless some entirely new kind of climate were created, rather than a redistribution of climates of the existing types. Many plants and animals—tomatoes, corn and horses, for example—also have experienced a range of climates during the process of spatial diffusion.

In summary, the changes expected do not appear to be unprecedented from the point of view of human experience or the experience of many other biota. They are not unprecedented for climate itself over long (geologic) time scales. They are not unprecedented on more limited time scales of a decade, or on regional spatial scales. They are much less than the changes that occur between seasons, or between day and night, or between one year and the next because of natural climate variability. The key question is: How will the projected climatic change differ from all the climate variations to which people, the economy, and ecosystems are accustomed?

Hypothesis 7: Impacts will be worse on less-developed countries than on developed countries.

7. Will Less-Developed Nations Suffer More? The notion that the impacts of global warming will be worse on less-developed countries, or LDCs, is based on the fact that these countries are more reliant for their well-being on production in primary sectors, especially agriculture, that are vulnerable to changes in weather and climate. Even if, as suggested above, agricultural impacts of warming will not necessarily be severe, there is evidence from geographical research that the costs of natural hazards are much greater in relation to national income in LDCs (*Figure 7*). The percent loss of gross national product appears to be about 20 times greater in LDCs. Moreover, it is generally observed that the poor suffer more in plagues and that, as Aaron Wildavsky once put it, "richer is safer."

On the other hand, LDCs may have flexibility. N. S. Jodha and Adolfo Mascarenhas

in 1985 described the impressive array of short-term adjustments and long-term adaptations that are available in self-provisioning societies in India and East Africa. There may be less sunk cost in infrastructure in LDCs. Having the benefit of a better forecast of the future, they may be able to "get it right." Several LDCs have particularly harsh present climates and may be open to the prospect of new climatic regimes. Most are also in tropical regions, where shifts in climate are predicted to be smaller.

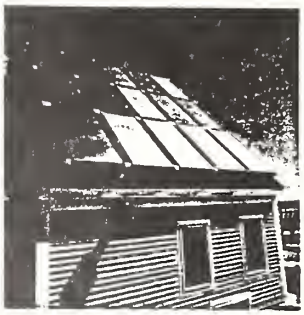
All the same, what research has been performed tends to confirm the view that LDCs are qualitatively and quantitatively more vulnerable. For example, a frost in Brazil's major coffee region in 1975 left some 600,000 people jobless. It is difficult to envision an equivalent impact in a developed nation. Similarly, more than 125,000 people are estimated to have lost their lives in the recent cyclone that struck Bangladesh, whereas only 20 deaths were attributed to Hurricane Hugo in the U.S. The problems of reduced income from carbon exports and possibly from higher short-run costs to implement environmentally sustainable development policies may loom as large or even much larger than increased costs from climatic hazards. Overall, the view that LDCs are more vulnerable is persuasive. It needs to be strengthened through additional research. The possibility exists that LDCs will suffer doubly, from both climatic impacts and emission-control strategies.

8. Are There Economical Hedging Strategies? Many studies of impacts culminate in a list of adaptive strategies that should be pursued. These typically recommend augmented efforts to increase efficiency in energy use; better management of water demand; promotion of research to develop drought-resistant strains of agricultural crops; and more prudent development of coastal zones.

The question that must be asked here is: Why are actions that are supposed to be prudent anyway, even without the added impetus of global warming, in fact being pursued in such a limited way? Part of the answer would seem to rest with the reality that prudence and efficiency are only partial goals of our overall systems. Considerations including timing, quality, economic cost and alternative uses of financial resources must be taken into account. Neither an individual, nor the society as a whole, invests more than a few percent of its income in hedging or insurance. Another part of the answer probably lies in the fact that there are barriers, in information and process, to adding up many partial justifications to constitute a full one.

The burden would seem to remain with those proposing the hedging and "tie-in" strategies to show the economics in detail. Based on the ideas here, it might be logical to begin by exploring such strategies in relation to water resources and ecosystem management. With regard to water, the focus would be on decreasing existing vulnerabilities that climatic change will make more severe. In some places the vulnerabilities could be decreased by better arrangements for transferring water to new uses, in others by building new structures, and in others by increasing the benefit of each gallon.

Preservation of natural ecosystems would involve a blend of *ex situ* and *in situ* methods. The former include botanical gardens, arboretums, nurseries, zoos, farms, aquariums, seed banks, microbial and tissue cultures, and gene libraries. *In situ* methods include preserving samples of representative ecosystems and habitat types and establishing corridors along which species can move to change their ranges in response to climatic change. Tools for calculation of risks, costs



Hypothesis 8: There are hedging strategies that are clearly economical.

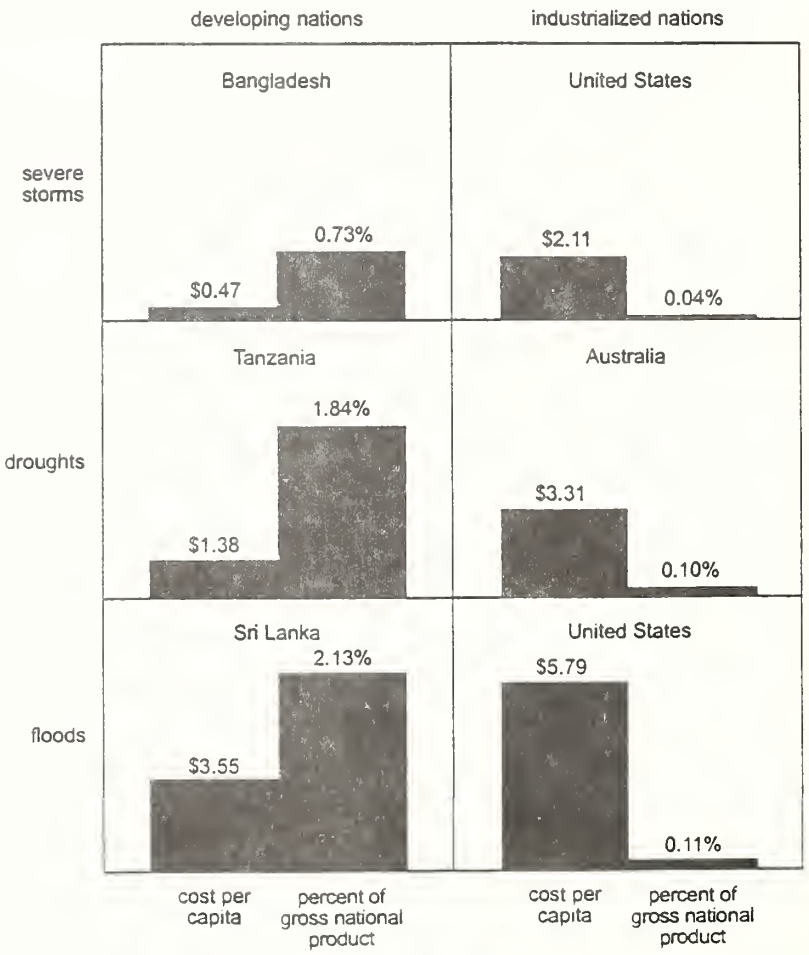


Figure 7. Natural hazards have a much greater impact on the national income of less-developed countries (LDCs) than on the economies of industrialized nations. On a per capita basis, the industrialized nations experience relatively high annual costs from natural hazards; however, in the LDCs hazard costs represent a much larger portion of gross national product. Hazard costs are calculated by combining direct damage losses and the costs of adjustment. (After Burton, Kates and White 1978.)

Photograph credits

Page 210
Photo Researchers, Inc.
Paolo Koch

Page 211
Photo Researchers, Inc.
Eunice Harris

Page 213
Photo Researchers, Inc.
Tom McHugh

Page 215
Photo Researchers, Inc.
Larry Miller

Page 216
Photo Researchers, Inc.
Larry Miller

Page 218 (top)
Photo Researchers, Inc.
Paul Fletcher/
Science Photo Library

Page 218 (bottom)
Photo Researchers, Inc.
Victor Englebert

Page 219
Photo Researchers, Inc.
Arthur Tress

and benefits should be applied in such areas to demonstrate the value of investments and how the timing and certainty of climatic change affect them.

Conclusions

Much of the conventional wisdom about impacts of global warming would appear as yet to have little support from research. The statements that embody this view need to be treated as hypotheses for testing. In every case, it would seem straightforward to design a research effort that could support or clarify the hypothesis in question. For the present, the hypotheses might be labeled myths, because to a considerable extent they are uncritically held views. Like more traditional myths, some will turn out to be profoundly true, and others will turn out to be in defiance of facts. In either case, they should be rigorously tested and examined. In the meanwhile, individuals, enterprises and governments should think carefully in acting on the basis of much of what is being said.

I would offer the following revised statements about climatic impacts, in the hope that they will inform the decision-making process:

1. It is very important whether the climatic change is expected.

2. It is very important how fast we can acquire better information.

3. There is likely to be a complex and shifting set of winners and losers.

4. There should be an increased focus on water resources and ecosystem preservation.

5. It is important to identify thresholds and discontinuities that may matter for impacts.

6. It is important to clarify how greenhouse-induced climatic change will differ from all the climatic variations that already occur.

7. There may be a double vulnerability of LDCs, both from climatic hazards and from strategies to limit emissions that may cause those hazards.

8. The economics of hedging strategies need to be demonstrated.

It will be helpful to have a more dynamic and variegated image of the greenhouse effect that takes greater account of the human capacity for social learning and adaptation. The prevailing image may influence importantly the identification of policies and impel us to place, and perhaps to misplace, some quite large investments.

Bibliography

Arnow, T. 1985. Rise of Great Salt Lake, Utah. In *National Water Summary 1984—Hydrologic Events, Selected Water-Quality Trends, and Ground-Water Resources*, Water Supply Paper 2275, 31–33. Reston, VA: U.S. Geological Survey.

d'Arge, R. C. 1979. Climate and economic activity. In *Proceedings of the World Climate Conference*. Geneva: World Meteorological Organization.

Ausubel, J. H. 1991. The role of technology in adaptation to climate. *Nature*, 350:649–652.

Bradley, R. S., H. Diaz, J. K. Eischeid, P. D. Jones, P. M. Kelley and C. M. Goodess. 1987. Precipitation fluctuations over northern hemisphere land areas since the mid-19th century. *Science* 237:171–175.

Broadus, J. 1990. Possible impacts of and adjustments to sea level rise: The cases of Bangladesh and Egypt. Woods Hole Oceanographic Contribution No. 7147. Woods Hole, Mass.: Woods Hole Oceanographic Institution.

Broecker, W. S. 1987. Unpleasant surprises in the greenhouse? *Nature* 328: 123–126.

Burton, I., R. W. Kates and G. F. White. 1978. *The Environment as Hazard*. New York: Oxford University Press.

Cardelino, C. A., and W. L. Chameides. 1990. Natural hydrocarbons, urbanization and urban ozone. *Journal of Geophysical Research* 95:13,971–13, 979.

CIAP. 1975. *Economic and Social Measures of Biologic and Climatic Change*. Climate Impact Assessment Program Monograph 6. DOT-TST-75-56. Washington, DC: U.S. Department of Transportation.

Easterling, W. E., III, M. L. Parry and Pierre Crosson. 1989. Adapting future agriculture to changes in climate. In *Greenhouse Warming: Abatement and Adaptation*, ed. N. J. Rosenberg, W. E. Easterling, III, P. R. Crosson and J. Darmstadter, 91–104. Washington, DC: Resources for the Future.

Glantz, M. H., ed. 1988. *Societal Responses to Regional Climatic Change: Forecasting by Analogy*. Boulder, CO: Westview.

Hansen, J. E., and S. Lebedeff. 1988. Global surface air temperatures: Update through 1987. *Geophysical Research Letters* 15:323–326.

Heathcote, R. L. 1985. Extreme event analysis. In *Climate Impact Assessment*, ed. R. W. Kates, J. H. Ausubel and M. Berberian, 369–401. SCOPE 27. Chichester: Wiley.

Hitt, K. J., and J. B. Miller. 1986. Great Lakes set record high water levels. In *National Water Summary 1985—Hydrologic Events and Surface-water Resources*, 35–40. Water Supply Paper 2300. Reston, VA: U. S. Geological Survey.

Intergovernmental Panel on Climate Change. 1990. *Potential Impacts of Climate Change*. Report from Working Group II to IPCC. Geneva: World Meteorological Organization.

Jaeger, J. W. 1988. *Developing Policies for Responding to Climatic Change*. A summary of discussions and recommendations of the workshops held in Villach (1987) and Bellagio (1987) under the auspices of the Beijer Institute, Stockholm, Sweden. WMO/TD No. 225. Geneva: World Meteorological Organization.

Jodha, N. S., and A. C. Mascarenhas. 1985. Adjustment in self-provisioning societies. In *Climate Impact Assessment*, ed. R. W. Kates, J. H. Ausubel and M. Berberian, 437–464. SCOPE 27. Chichester: Wiley.

Karl, T. R., and W. E. Reibsame. 1984. The identification of 10- to 20-year climate fluctuations in the contiguous United States. *Journal of Climate and Applied Meteorology* 23:950–966.

Kettunen, L., J. Mukula, V. Pohjonen, O. Rantenen and U. Varjo. 1988. The effects of climatic variations on agriculture in Finland. In *The Impact of Climatic Variations on Agriculture*, ed. M. L. Parry, T. R. Carter and N. T. Konijn, vol. 1, Assessment in Cool Temperate and Cold Regions, 513–614. Dordrecht: Kluwer.

Lashof, D. A., and D. A. Tirpak, eds. 1989. *Policy Options for Stabilizing Global Climate*. Draft report to Congress.

Office of Policy, Planning and Evaluation, Environmental Protection Agency. Washington, DC: U. S. Environmental Protection Agency.

MacDonald, G. J. 1990. Role of methane clathrates in past and future climates. *Climatic Change* 16:247–282.

Margolis, M. 1980. Natural disaster and socioeconomic change: Post-frost adjustments in Parana, Brazil. *Disasters* 4:231–235.

Mearns, L. O., R. W. Katz and S. H. Schneider. 1984. Changes in the probabilities of extreme high temperature events with changes in global mean temperature. *Journal of Climate and Applied Meteorology* 23:1601–1613.

Morrisette, P. M. 1988. The rising levels of the Great Salt Lake: An analogue of societal adjustment to climate change. In *Societal Responses to Regional Climatic Change: Forecasting by Analogy*, ed. M. H. Glantz, 169–195. Boulder, CO: Westview.

National Academy of Sciences. 1991. *Policy Implications of Greenhouse Warming*. Synthesis Panel, Committee on Science, Engineering, and Public Policy. Washington, DC: National Academy Press.

National Academy of Sciences. 1991. *Policy Implications of Greenhouse Warming: Report of the Adaptation Panel*. Committee on Science, Engineering, and Public Policy. Washington, DC: National Academy Press.

National Research Council. 1983. *Changing Climate*. Washington, DC: National Academy Press.

National Research Council. 1987. *Responding to Changes in Sea Level Rise: Engineering Implications*. Washington, DC: National Academy Press.

Overpeck, J. T., D. Rind and R. Goldberg. 1990. Climate-induced changes in forest disturbance and vegetation. *Nature* 343:51–53.

Palutikof, J. 1983. The impact of weather and climate on industrial production in Great Britain. *Journal of Climatology* 3:65–79.

Peters, R. L., and J. D. S. Darling. 1985. The greenhouse effect and nature reserves. *Bioscience* 11:707–717.

Rind, D., R. Goldberg and R. Ruedy. 1989. Change in climate variability in the 21st century. *Climatic Change*. 14:5–37.

Roeckner, E., U. Schlese, J. Biercamp and P. Loewe. 1987. Cloud optical depth feedbacks and climate modeling. *Nature* 329:138–140.

Schelling, T. C. 1983. Climatic change: Implications for welfare and policy. In *Changing Climate*, National Research Council, 449–482. Washington, DC: National Academy Press.

Schneider, S. H. 1989. *Global Warming: Are We Entering the Greenhouse Century?* San Francisco: Sierra Club.

Strain, B. R., and J. D. Cure. 1985. *Direct Effects of Increasing Carbon Dioxide on Vegetation*. DOE/ER-0238. Washington, DC: U. S. Department of Energy.

Vellinga, P., and S. P. Leatherman. 1989. Sea level rise, consequences and policies. *Climatic Change* 15:175–190.

Waggoner, P. E., ed. 1989a. *Climatic Change and U.S. Water Resources*. Report of AAAS Panel on Climate and Water. New York: Wiley.

Waggoner, P. E. 1989b. Anticipating the frequency distribution of precipitation if climate change alters its mean. *Agricultural and Forest Meteorology* 47:321–337.

Wildavsky, A. 1980. Richer is safer. *The Public Interest*. Autumn.

Yoshino, M. M., T. Horie, H. Seino, H. Tsuji, T. Uchijima and Z. Uchijima. 1988. The effects of climatic variations on agriculture in Japan. In *The Impact of Climatic Variations on Agriculture*, ed. M. L. Parry, T. R. Carter and N. T. Konijn, vol. 1, Assessment in Cool Temperate and Cold Regions, 725–868. Dordrecht: Kluwer.

Apocalypse sells well in the media and even better on Capitol Hill. And that is why fears of the greenhouse effect threaten to push the U.S. into a costly environmental mistake.

THE GLOBAL WARMING PANIC

By Warren T. Brookes

On Nov. 7 the U.S. and Japan shocked environmentalists around the world by refusing to sign a draft resolution at a Netherlands international conference on global climate change calling for the "stabilization" of emissions of carbon dioxide (CO_2) and other "greenhouse gases" by the year 2000. Instead, they made the conference drop all reference to a specific year, and to a specific CO_2 reduction target. The Bush Administration view was set forth by D. Allan Bromley, the presidential science adviser, in testimony to Senator Albert Gore's subcommittee on Science, Technology & Space. "My belief is that we should not move forward on major programs until we have a reasonable understanding of the scientific and economic consequences of those programs."

President Bush was immediately savaged by environmentalists, and by politicians like Senator Gore (D–Tenn.). The Bush viewpoint does not sit too well with most of the media, either. Last January *Time* published a cover story on environmental catastrophes, declaring that greenhouse gases could create a climatic calamity. The *New York Times* weighed in a month ago with a story about how melting polar ice would flood the nations that can least afford to defend themselves, Third World countries like Bangladesh and India. Or perhaps you have seen the ads for Stephen Schneider's *Global Warming*, accompanied by a blurb from Senator Tim Wirth (D–Colo.). In his book this well-known climatologist paints a future of seas surging across the land, famine on an epidemic scale and ecosystem collapse.

Is the earth really on the verge of environmental collapse? Should wrenching changes be made in the world's industry to contain CO_2 buildup? Or could we be witnessing the 1990s version of earlier scares: nuclear winter, cancer-causing cranberries and $100 oil? The calamitarians always have something to worry us about. Consider this: In his 1976 book, *The Genesis Strategy*, Schneider lent support to the then popular view that we could be in for another ice age, "perhaps one akin to the Little Ice Age of 1500-1850. Climatic variability, which is the bane of reliable food production, can be expected to increase along with the cooling."

At the very moment Bromley was testifying to Gore's subcommittee, MIT's prestigious *Technology Review* was reporting on the publication of an exhaustive new study of worldwide ocean temperatures since 1850 by MIT climatologists Reginald Newell, Jane Hsiung and Wu Zhongxiang. Its most striking conclusion: "There appears to have been little or no global warming over the past century." In fact, the average ocean temperature in the torrid 1980s was only an eighth of a centigrade degree (a quarter of a Fahrenheit degree) higher than the average of the 1860s. Ocean temperature is now virtually the same as it was in the 1940s. Since two-thirds of the buildup of CO_2 has taken place since 1940, the MIT data blow all of the global warming forecasts into a cocked hat. President Bush wisely told reporters: "You can't take a policy and drive it to the extreme and say to every country around the world, 'You aren't going to grow at all.' "

That is the central issue of the global warming debate, and it explains why the U.S. and Japanese position was supported by some 30 other developing nations which see that just as Marxism is giving way to markets, the political "greens" seem determined to put the world economy back into the red, using the greenhouse effect to stop unfettered market-based economic expansion.

In simplest terms, the earth's atmosphere does operate as a greenhouse. In addition to oxygen, nitrogen and water vapor, the atmosphere contains several gases that trap radiated heat, including methane and CO_2. Carbon dioxide is essential not only to warmth but to vegetation. It is also essential to life in another way: Without its heat-containing effect the planet would freeze, like the atmospherically naked moon.

Throughout most of human history that atmospheric blanket has held global temperatures at an average of about 60 degrees F., plus or minus 5 degrees F. During most of human history, the CO_2 concentration in that blanket has, until this century, hovered around 270 parts per million, although in earlier geologic epochs it reached as high as 20,000.

Over the last 100 years the CO_2 concentration has risen from 270 to today's level of 350. The culprit: man. Most of the greenhouse gas increase is the result of fossil fuel consumption. Add to that the rise in other man-generated trace gases—methane, nitrogen oxides and chlorofluorocarbons—and total greenhouse gases are now at 410 ppm. In other words, because of the combined effect of these gases, we have already gone over halfway to a doubling of CO_2. Even so, there has been less than half a degree of warming in the last 100 years.

What do the environmental pessimists make of all this? The earliest versions of their computer "general circulation models" predicted that the earth would warm up by anywhere from 3 to 5 degrees centigrade, or 5 to 9 degrees Fahrenheit, by the year 2050. The most extreme scenarios warn of coastal flooding (from melting ice caps) and rising inland droughts. However, as the level of sophistication of the models has risen, these forecast effects have been steadily reduced to a new range of 1.5 to 2.5 degrees centigrade.

One major exception to this declining rate of doom is the model run by James Hansen of the National Aeronautics & Space Administration, who shocked a congressional hearing in

June 1988 during the middle of a scorching near-nationwide drought, by saying he was "99% confident" the greenhouse effect is now here.

Even though the vast majority of the climatological community was outraged by Hansen's unproven assertions, environmental advocate Stephen Schneider notes in *Global Warming*, "Journalists loved it. Environmentalists were ecstatic. Jim appeared on a dozen or more national television news programs. . . . "

By the end of 1988, with Hansen and Schneider's enthusiastic support, global warming was deeply embedded in the public consciousness. Now over 60% of the public is convinced it will worsen, even as the evidence of that alleged trend is under increasingly sharp and solid scientific attack.

On the contrary, that attack has been used as a premise for even more immediate action. As one TV anchorman argued, "Even if we aren't sure it's true, shouldn't we take precautions and act now as if it were?"

Unfortunately, "taking such precautions" could well spell the end of the American dream for us and the world. Once CO_2 is in the atmosphere, we can't easily remove it. Since most of the forecast rise in the gas is a function of simple economic and population growth in the Third World, there is no realistic economic way to prevent a CO_2 doubling without slashing growth and risking a revolt of the have-not nations against the haves. The Washington, D.C.-based Center for Strategic & International Studies points out that, even though the U.S. is now the largest carbon fuel user, it's the developing countries that will quadruple their energy consumption by 2025. "By the middle of the next century, they will account for the bulk of the greenhouse gases emitted into the atmosphere, even if they succeed in doubling energy efficiency."

The Environmental Protection Agency finds that just to stabilize U.S. CO_2 emissions at present levels would force 30% taxes on oil and coal, while to meet environmentalists' demands for a 20% reduction in U.S. CO_2 emissions would require a tax of $25 per barrel on oil, and $200 a ton on coal, effectively doubling U.S. energy costs.

Unfortunately, the popular media don't seem to care. In May the national press erupted in a two-day firestorm when Hansen told Senator Gore's subcommittee that the Office of Management & Budget had censored his florid global warming testimony by adding the modest caveat, "These changes should be viewed as estimates from evolving computer models and not as reliable predictions."

Yet, at the moment of that testimony, 61 of the world's top climatologists, gathered for a five-day workshop in Amherst, Mass., were largely agreeing with OMB. *Science* magazine reported that most of the attendees were pleasantly surprised by OMB's efforts to control Hansen: "I can't say I agree with censorship, but it seems OMB has better people than I thought. I'd have to agree with their angle," said Rick Katz of the National Center for Atmospheric Research, one of the leading modelers.

Conference leader Michael Schlesinger, another top modeler (University of Illinois), agreed: "[Hansen's] statements have given people the feeling the greenhouse effect has been detected with certitude. Our current understanding does not support that. Confidence in its detection is now down near zero."

That conclusion was buttressed by one of the deans of U.S. climatology, Reid Bryson, a founder of the Institute for Environmental Studies at the University of Wisconsin, who said in July: "The very clear statements that have been made [by Hansen] that the greenhouse warming is here already and that the globe will be 4 degrees [centigrade] warmer in 50 years cannot be accepted."

On Dec. 24, 1988, Hansen received an unwelcome Christmas present in the form of a new research paper by one of the world's most universally respected climatologists, Thomas Karl, and two of his colleagues at the National Oceanographic & Atmospheric Administration, Kirby Hanson and George Maul. Their review of the best climate record in the world—that of the 48 contiguous United States—concluded: "There is no statistically significant evidence of an

overall increase in annual temperature or change in annual precipitation for the contiguous U.S. 1895-1987." Look at the chart on pages 96-97. As Karl says in an interview, "If there is a greenhouse warming effect, you can't find it in the U.S. records."

That news alone should have cooled off the global warming movement. But the environmentalists accepted Hansen's dismissal of the paper as "not significant" because the data covered only 1.5% of the earth's surface, not nearly enough to identify major trends.

But MIT meteorologist Richard Lindzen says that Hansen's rebuttal is out of line. He points out that because of the law of large numbers—the fact that a large enough sample is likely to give an accurate picture of a larger population—"the absence of any trend in the record of the contiguous U.S. leads to the suspicion that all the trends in the global record may be spurious."

The major reason for this is that when you fully subject global temperature records (as Karl did the U.S. records) to adjustment for the effects of urbanization (cities are heat islands that artificially inflate temperature records), the global warming trend since 1880 has been only a third of a degree centigrade, and over the Northern Hemisphere land masses, no trend at all.

Here's another fact, noted by Hugh Ellsaesser of Lawrence Livermore Laboratories, that should trouble the calamity theorists: Most of the past century's warming trend took place by 1938, well before the rise in CO_2 concentration. From 1938 to 1970 temperatures plunged so sharply a new ice age was widely forecast. Furthermore, the warming trend since 1976 has been just the opposite of that forecast by the greenhouse model, with *cooling* in both the northern Pacific and North Atlantic.

In fact, the Northern Hemisphere shows no net change over the last 55 years, during which CO_2 concentration rose from approximately 300 to 350 ppm and other thermally active trace gases were in their steepest growth phases.

In spite of this clear lack of correlated warming evidence, one of the leading climate models now predicts that a 1% annual rise in CO_2 should, over 30 years, produce a 0.7-degree centigrade warming. But when Patrick Michaels of the University of Virginia applied that formula to the period from 1950 to 1988, when greenhouse

gases rose 1.2% per year, he found a tiny 0.2-degree warming in land temperatures, where the model would have predicted 1.3 degrees. When a model cannot come within 500% of explaining the past, it is useless as a predictor of anything.

As Reid Bryson concludes in a 1988 paper, "A statement of what the climate is going to be in the year A.D. 2050 is a 63-year forecast. Do the models have a demonstrated capability of making a 63-year forecast? No. A 6.3-year forecast? No. Have they successfully simulated the climatic variation of the past century and a half? No. They are marvels of mathematics and computer science, but rather crude imitators of reality."

The major weakness of the models is their assumption that the CO_2 buildup is the significant climate variable, and should *ceteris paribus* (all other things being equal) generate warming. But, as it turns out, the *ceteris* are decidedly not *paribus*.

One of those variables is cloud cover, which is at least 100 times more powerful in affecting temperatures than greenhouse gases and is infinitely variable. Yet, because cloud cover has been documented only for a decade or so (by weather satellites), the models have little to go on. Until recently, the modelers assumed that warmth gave rise to the kind of clouds that trap heat, contributing still further to warming, in a vicious cycle. But in June 1988, V. Ramanathan of the University of Chicago and a team of scientists at NASA concluded from preliminary satellite data that "clouds appear to cool earth's climate," possibly offsetting the atmospheric greenhouse effect.

The supreme irony is that this "cooling effect," most pronounced in the Northern Hemisphere, coincides with the paths of coal-burning emission plumes with their high concentration of sulfur dioxide. That confirms a long-held thesis that sulfur dioxide creates "cool clouds." Of course, it is very upsetting to an environmentalist to discover that a pollutant has a beneficial side effect.

Sulfur dioxide emissions not only acidify rain, they combine with water vapor to form what are known as "aerosols," which have the effect of brightening clouds and making them reflect more heat away from the earth. Wisconsin's Reid Bryson described this effect as early as 20 years ago. Bryson's thesis was scorned at the time. But last June, Thomas Wigley, one of England's top climatologists and a global warming enthusiast, conceded in a paper in *Nature* magazine that sulfur dioxide cooling "is sufficiently large that the effects may have significantly offset the temperature changes that resulted from the greenhouse effect."

Michaels says this could also explain in part why U.S. daytime highs (when brighter clouds have the most cooling effect) have actually declined substantially in the last 50 years, even as the nighttime lows have risen. "This should make you wonder," says Michaels, "why Hansen [and others] have only perturbed their models with CO_2, and not with SO_2 as well. If you only perturb the model with CO_2, it will predict the greenhouse warming effect. If you only perturb it with SO_2, you get an ice age."

Hugh Ellsaesser says the main reason the models have been so completely wrong in "predicting" the past is that they completely ignore the countervailing, thermostatic effects of the hydrological cycle of evaporation and condensation. Two-thirds of the predicted global warming is due not directly to CO_2's radiative power but to an indirect effect: Carbon dioxide warming supposedly causes a threefold amplification of water vapor surface evaporation into the atmospheric blanket.

But Ellsaesser says in the warmer, tropical latitudes, where the temperature change from sea-level upward is most rapid, evaporation has the opposite effect. There, water vapor rises by deep convection in fast-rising towers. This in turn leads to more rapid condensation and precipitation, which then causes a drying and thinning of the upper atmosphere in a process called subsidence. "In the lower latitudes, a rise in CO_2 emissions will produce a 3-to-1 rise in greenhouse blanket *thinning* due to condensation. That's exactly the opposite of what the models predict," he says.

An eminent British scientist, Sir James Lovelock, says this hydrological process "is comparable in magnitude with that of the carbon dioxide greenhouse, but in opposition to it." National Oceanographic scientist Thomas Karl agrees: "We will eventu-

ally discover how naive we have been in not considering CO_2's effects on cloud cover and convection. As CO_2 speeds up the hydrological cycle, more convection creates more clouds and more cooling. So, the greenhouse effect could turn out to be minimal, or even benign."

MIT's Richard Lindzen thinks that correcting for deep convection alone could lower the global warming estimates by a factor of six. As a result, he says, "It is very unlikely that we will see more than a few tenths of a degree centigrade from this cause [CO_2] over the next century."

In the face of such mounting evidence, U.S. businesses may stop worrying about devastating legislative enactments. That could be a mistake. As Nobel economist James Buchanan argues, what drives Washington policymaking is not economic or scientific realities but "public choice," the pursuit of power and funding.

The public choice potential of global warming is immense. Under a global warming scenario, the EPA would become the most powerful government agency on earth, involved in massive levels of economic, social, scientific and political spending and interference, on a par with the old Energy Department. Don't forget the energy crisis: During the 1970s, a great many less-than-honest scientists confidently predicted the world was about to run out of fossil fuels, and that by 1985, we'd be paying $100 a barrel for oil, or more. We wasted billions on energy subsidies.

Senator Albert Gore is evidence of this public choice phenomenon. He seems determined to run his next presidential campaign at least in part on climate change, saving Mother Earth. Every year, at least one-sixth of the U.S. is classified by the government's Palmer Index as being in drought. Even though that index overstates the case, Gore could be looking at some very big political states—maybe California or Texas or Iowa—where his message will resonate with farmers and business. All he has to do is wait for a warm spell, and capitalize on what mathematicians call noise in the statistics.

Patrick Michaels explains: "We know that the Pacific Ocean current known as El Niño tends to warm and cool in two-year cycles. Just as its warming cycle produced the 1987-88 droughts, in 1989 it cooled sharply, making the U.S. much cooler and wetter than Hansen had forecast, and that is likely to happen in 1990, again. But that means that 1991 and 1992 should be warmer and drier than usual as the El Niño current warms. It won't matter that this has nothing to do with global warming, the media will perceive it that way, and people will tend to believe it."

Bernard Cohen, a physicist at the University of Pittsburgh, warns, in a 1984 book: "Our government's science and technology policy is now guided by uninformed and emotion-driven public opinion rather than by sound scientific advice. Unless solutions can be found to this problem, the U.S. will enter the 21st century declining in wealth, power and influence. . . . The coming debacle is not due to the problems the environmentalists describe, but to the policies they advocate."

"Global warming" may well prove Cohen right. ■

Original article contains photos of Senator Gore, James Hansen, Reid Bryson, Richard Lindzen, Hugh Ellsasser, and Patrick Michaels.

SCIENTIFIC AMERICAN

Global Climatic Change

by Richard A. Houghton and George M. Woodwell

SCIENTIFIC AMERICAN
APRIL 1989
VOL. 260, NO. 4 PP. 36–44

SCIENTIFIC AMERICAN April 1989 Volume 260 Number 4

Global Climatic Change

Evidence suggests that production of carbon dioxide and methane from human activities has already begun to change the climate and that radical steps must be taken to halt any further change

by Richard A. Houghton and George M. Woodwell

The world is warming. Climatic zones are shifting. Glaciers are melting. Sea level is rising. These are not hypothetical events from a science-fiction movie; these changes and others are already taking place, and we expect them to accelerate over the next years as the amounts of carbon dioxide, methane and other trace gases accumulating in the atmosphere through human activities increase.

The warming, rapid now, may become even more rapid as a result of the warming itself, and it will continue into the indefinite future unless we take deliberate steps to slow or stop it. Those steps are large and apparently difficult: a 50 percent reduction in the global consumption of fossil fuels, a halting of deforestation, a massive program of reforestation.

There is little choice. A rapid and continuous warming will not only be destructive to agriculture but also lead to the widespread death of forest trees, uncertainty in water supplies and the flooding of coastal areas. When the ice now covering the Arctic Ocean melts, further unpredictable changes in the global climate will ensue. There may be controversy over whether the data are adequate and whether the warming is caused by changes in the atmosphere. Yet there is an unusually powerful consensus among climatologists that the dominant influence on global climate over the next centuries will be a warming driven by the accumulation of heat-trapping gases. The consequences are threatening enough so that many scientists, citizens and even political leaders are urging immediate action to halt the warming.

RICHARD A. HOUGHTON and GEORGE M. WOODWELL have collaborated for more than 20 years on topics of environmental concern. Houghton is an ecologist and a senior scientist at the Woods Hole Research Center in Woods Hole, Mass. For the past 10 years he has been concerned with the global carbon cycle and has specialized in the response of ecosystems, particularly forests, to climatic change. Woodwell is also an ecologist and is the director of the Woods Hole Research Center. He and Houghton hope to be able, along with their Woods Hole colleagues, to advance improved models for the management of renewable resources.

The fact that heat-trapping gases have been accumulating in the atmosphere is well established. Since the middle of the 19th century the amount of atmospheric carbon dioxide has increased by about 25 percent. The increase has come about because human activities, especially the burning of coal and oil and the destruction of forests, have released greater quantities of carbon dioxide into the atmosphere than have been removed by diffusion into the oceans or by photosynthesis on land [*see illustration on page 4*].

The increase in carbon dioxide appears trifling when one considers that the total amount in the atmosphere is a little more than .03 percent by volume. But in spite of its low concentration, carbon dioxide and several other gases present in even smaller amounts have an important role in determining the temperature of the earth. In contrast to both nitrogen and oxygen, which together make up more than 99 percent of the atmosphere, these trace gases absorb infrared radiation, or radiant heat. Since in this regard they act much like the glass over a greenhouse, they are commonly referred to as greenhouse gases.

Because the total amount of greenhouse gases is small, their concentrations are easily changed. An increase in the concentration of any one of them increases the atmosphere's capacity to retain heat and raises the temperature at which the atmosphere comes into equilibrium with the energy it receives from the sun. In recent years investigators have recognized that the atmospheric burden of greenhouse gases other than carbon dioxide, such as methane (CH_4), nitrous oxide (N_2O) and the chlorofluorocarbons (CFC's), is also growing at an increasing rate. By the mid-1980's, in fact, these gases had reached levels at which their combined effect approached that of carbon dioxide.

In this article we emphasize the role of carbon dioxide and methane because they are the principal contributors to the current warming, because their concentrations are strongly influenced by biological processes and because slowing or stopping the global warming will require control of carbon dioxide emissions in particular.

Global warming due to the accumulation of heat-trapping gases, particularly carbon dioxide, was predicted at the turn of the century by Svante Arrhenius in Sweden and Thomas C. Chamberlin in the U.S. Systematic research on the atmospheric accumula-

tion of carbon dioxide began only in 1958. Since then Charles D. Keeling of the Scripps Institution of Oceanography has provided a continuous record of the carbon dioxide level at various stations, the best-known of which is at Mauna Loa in the Hawaiian Islands [*see illustration on page 5*].

Information on the earth's temperature has been more difficult to accumulate. Strong evidence for global warming became available by late 1988. The most direct evidence lies in temperature records from around the world. James E. Hansen of the National Aeronautics and Space Administration's Goddard Institute of Space Studies and his colleagues have analyzed temperature records going back to 1860. Their analyses suggest that the average global temperature has increased by from .5 to .7 degree Celsius since that year. The greatest increase has taken place in the past decade; this recent warming is both statistically significant and consistent with their experience based on theory and on models of the global climatic system.

Thomas M. L. Wigley and his colleagues, working independently at the University of East Anglia in England, have also shown the increase in average global temperature. The rise has

HOLE-IN-THE-WALL GLACIER in Wrangell-St. Elias National Park, Alaska, is shown in an aerial view. The exposed ground at the foot of the glacier exhibits striations and moraines, the piles of debris left by a moving glacier; the ground has not had time to grow vegetation. All these are signs of recent glacial retreat. Similar behavior of a number of glaciers around the world *(see illustration on page 7)*, the increasing depth to permafrost and other data suggest that warming has continued since the last glacial period. Its cause, however, extending back long before the current buildup of greenhouse gases, remains a puzzle.

not been observed in all regions: a recent analysis of climate records by Kirby Hanson and his colleagues at the National Oceanic and Atmospheric Administration shows no trend in temperature for the contiguous U.S. Such regional variation is not unexpected; the contiguous U.S. covers only 1.5 percent of the globe's surface.

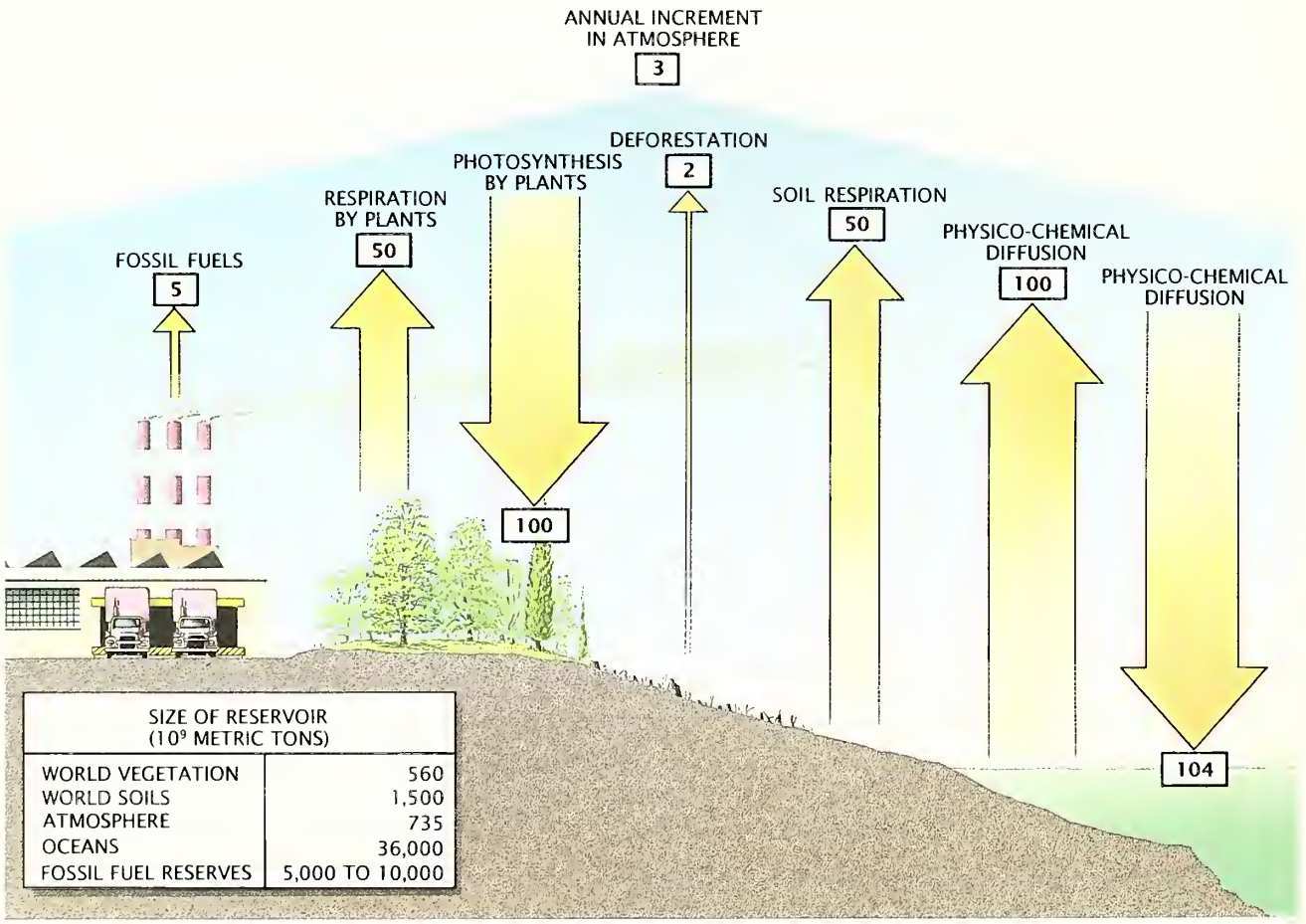
The observed rise in global temperature has not been steady and is clearly not simply a response to the accumulation of greenhouse gases. There was, for example, a decline in the mean global temperature between 1940 and 1965 in spite of the continued increase of heat-trapping gases in the atmosphere. Nevertheless, Phil D. Jones, one of Wigley's collaborators, has just recently reported that the global temperature has risen about .5 degree C since the beginning of the century and that the six warmest years on record were 1988, 1987, 1983, 1981, 1980 and 1986 in that order.

If a .5-degree temperature change seems insubstantial, one should remember that in 1816, the "year without a summer," the mean global temperature drop was also less than one degree. It was nonetheless sufficient to cause frosts in June in New England and widespread crop failures [see "The Year without a Summer," by Henry Stommel and Elizabeth Stommel; SCIENTIFIC AMERICAN, June, 1979]. The heat and drought that have afflicted North America and other regions of the earth in recent years are consistent with the predictions of a global warming trend.

There are other indications of an accelerated warming. According to Arthur H. Lachenbruch and B. Vaughn Marshall of the U.S. Geological Survey, the depth to permafrost in the Alaskan and Canadian Arctic has increased in recent decades. The average temperature of Canadian lakes has increased; the annual maximum extent of sea ice surrounding the Antarctic continent and in the Arctic seas appears to be declining; inland glaciers throughout Europe and elsewhere have receded.

These observations are consistent with predictions made by climatologists on the basis of theory aided by general circulation models. Several such global models exist and, although analyses based on them do not agree in detail, the general predictions are consistent with theory and experience. Climatologists expect that the greatest warming will occur at higher latitudes in winter. In these latitudes the warming, according to the models, will probably be at least twice the global average. In addition it is expected that the upper atmosphere will cool as the lower atmosphere warms and that there will be less precipitation and less moisture in the soil at lower latitudes. All these trends have been reported in recent years.

Data such as those are always open to further analyses, interpretation and augmentation. They invariably appear to suffer from inadequacies of



ANNUAL CARBON FLUXES are shown in units of one billion (10^9) metric tons. Photosynthesis on land removes about 100 billion tons of carbon from the atmosphere annually in the form of carbon dioxide. Plant and soil respiration each return about 50 billion tons. Fossil-fuel burning and deforestation release into the atmosphere respectively about five and two billion tons. Physicochemical processes at the sea surface release about 100 billion tons into the atmosphere and absorb about 104. The net atmospheric gain is about three billion tons annually. The table lists the world's major carbon reservoirs.

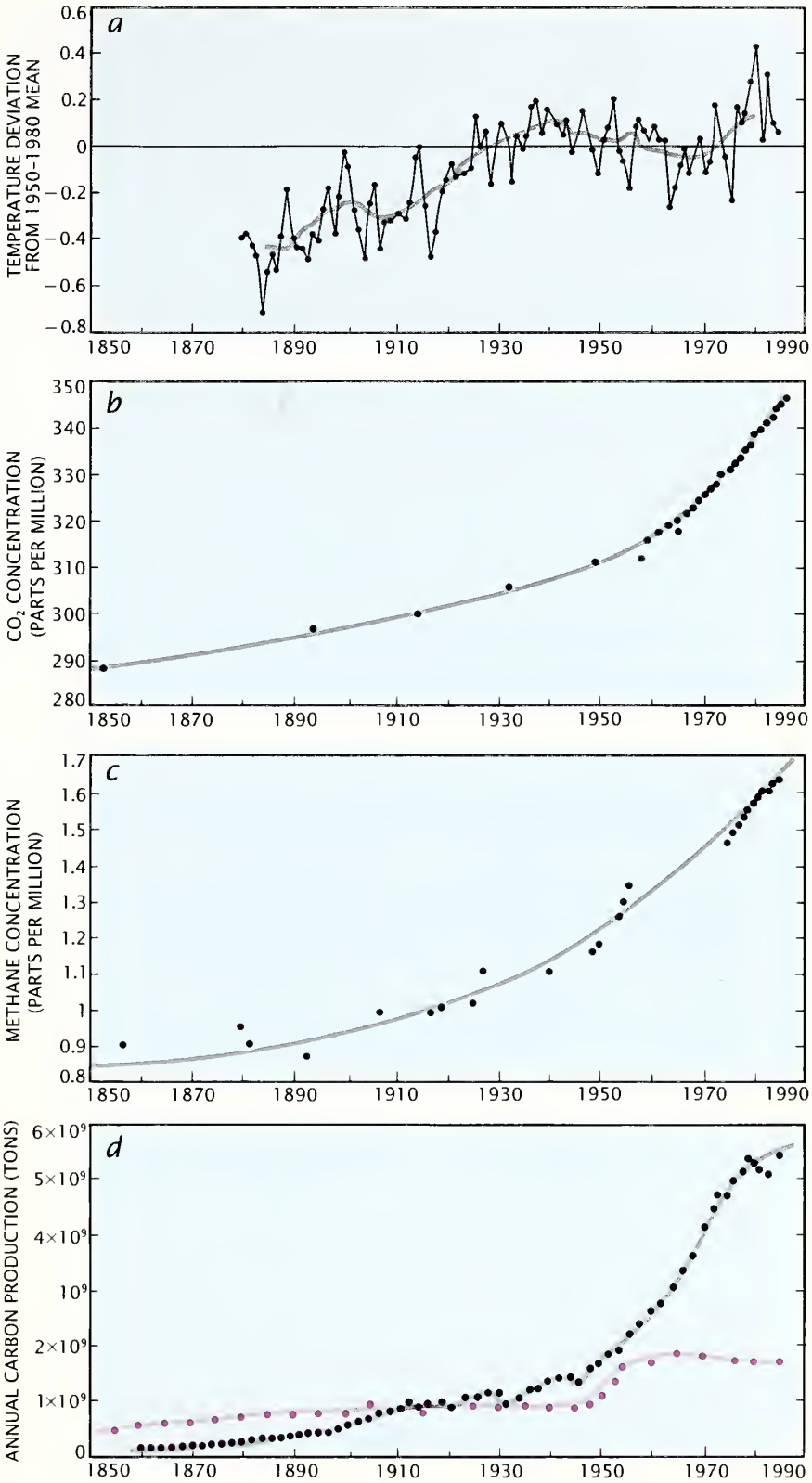
measurement and uncertainties about whether the period over which the measurements were taken was long enough to be significant. Investigators are currently improving the data and the analyses, but the fact remains that the observations described above, taken together with the rising concentration of greenhouse gases, constitute strong evidence that the process anticipated nearly a century ago by Arrhenius is under way.

One can learn much about potential future changes in climate by examining past climatic change. A mere 15,000 years ago glaciers covered much of North America and northern Europe. Were changes in the composition of the atmosphere involved in the great climate swings that brought glacial and interglacial periods? The answer is not completely clear, but one of the most important advances in recent years has been the ability to determine atmospheric composition in previous eras from tiny samples of air trapped in glacial ice. In particular, determination of the atmospheric composition during periods of glacial expansion and retreat has been made possible by data obtained from an ice core drilled by a joint French-Soviet team at the Antarctic Vostok station.

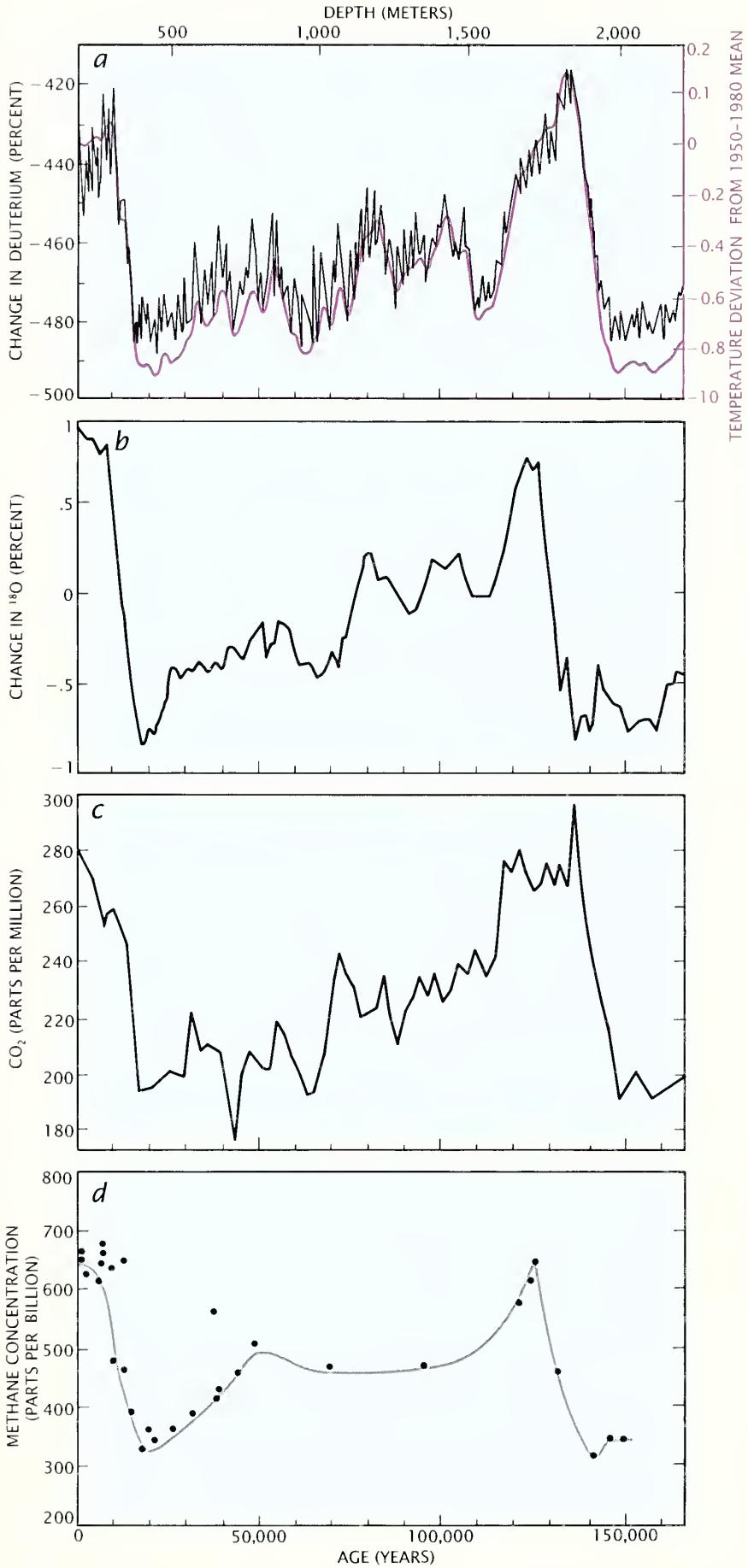
The Vostok core, as it is called, was 2,000 meters in length, long enough to sample ice dating through the past 160,000 years [*see illustration on next page*]. The data show fluctuations in temperature of up to 10 degrees; such fluctuations are derived from changes in the isotopic ratios in the core. It is well established, for example, that the ratio of the two common isotopes of oxygen, ^{18}O and ^{16}O, in cores of marine sediments reflects past temperature changes.

The Vostok data also show how the abundances of atmospheric gases have fluctuated with temperature over the past 160,000 years: the higher the temperature, the greater the concentration of carbon dioxide and vice versa. To be sure, the correlation of carbon dioxide with temperature does not establish whether changes in atmospheric composition caused the warming and cooling trends or were caused by them. Although the carbon dioxide content follows temperature very closely during periods of deglaciation, it apparently lags behind temperature during periods of cooling.

Although there is tight statistical coupling between carbon dioxide and temperature throughout the record, the temperature changes are from five



CORRELATION among the global temperature change, level of heat-trapping gases and carbon dioxide emissions is shown in the first three graphs for the past 140 years. In graph *a* both the annual mean temperature (*spiky curve*) and the five-year running mean (*smooth curve*) are plotted. Graphs *b* and *c* show the atmospheric carbon dioxide and methane content respectively. Pre-1958 data come from analyses of air trapped in bubbles of glacial ice from various sites around the world. The annual production of carbon from fossil-fuel burning (*black*) and from change in land use (*color*) is shown in *d;* the last data were obtained from historical sources.



to 14 times greater than would be expected on the basis of the radiative properties of carbon dioxide alone. This relation suggests that quite aside from changes in greenhouse gases, certain positive feedbacks are amplifying the response. Such feedbacks might involve ice on land and sea, clouds or water vapor, which also absorb radiant heat.

Other data from the same Vostok core sample show that methane also closely follows temperature and carbon dioxide. The methane concentration nearly doubled, for example, between the peak of the penultimate glacial period and the following interglacial period. Within the present interglacial period it has more than doubled in just the past 300 years and is rising rapidly. Although the concentration of atmospheric methane is more than two orders of magnitude lower than that of carbon dioxide, it cannot be ignored: the radiative properties of methane make it 20 times more effective molecule for molecule than carbon dioxide in absorbing radiant heat. On the basis of Hansen's radiative-convective model, which includes chemical feedbacks, methane appears to have been about 25 percent as important as carbon dioxide in the warming that took place during the most recent glacial retreat 8,000 to 10,000 years ago.

How can a global rise in temperature be expected to cause greater releases of carbon dioxide and methane into the atmosphere? In the process of photosynthe-

VOSTOK ICE-CORE DATA reveal a correlation between certain gas concentrations and temperature over the past 160,000 years. The ice core, 2,200 meters long, contains bubbles of air with carbon dioxide and methane that were trapped at different depths (*top scale*) and hence at different times (*bottom scale*). Several independent methods have established that the deuterium concentration in ice is a good measure of past temperature; both temperature and deuterium level are plotted in *a*. More traditional is the use of the oxygen isotope ^{18}O to track temperature; curve *b* is almost identical with *a*. The remarkable agreement with the shape of the Vostok-station carbon dioxide curve *c* argues that carbon dioxide can also serve as a global thermometer. Data on Antarctic methane compiled in 1985 and 1986 from several stations (*d*) strengthens the conclusion that levels of greenhouse gases are positively correlated with temperature and may actually influence it.

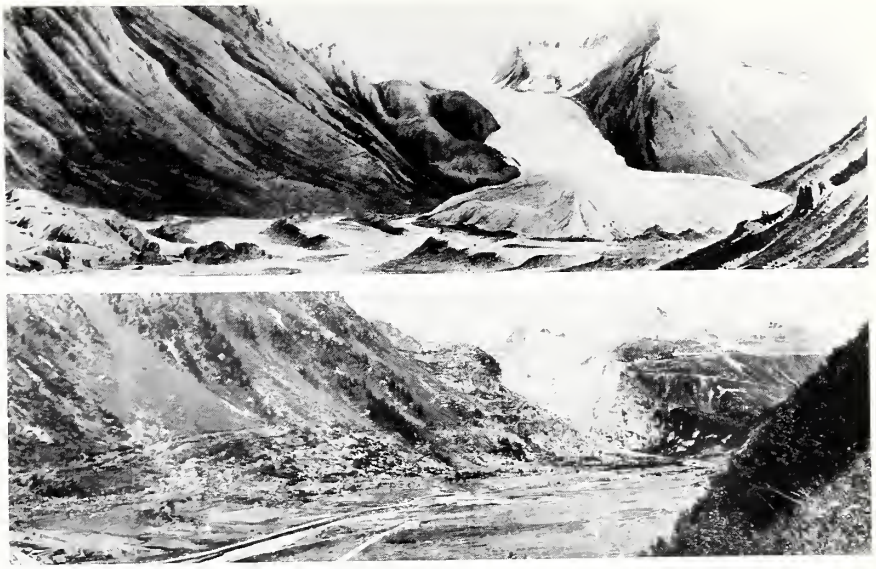
sis terrestrial plants remove about 100 billion tons of carbon from the atmosphere per year, or about 14 percent of the total atmospheric carbon content. An approximately equal amount of carbon is returned to the atmosphere through the processes of plant respiration and decay of organic matter. Because the fluxes are a substantial fraction of the carbon dioxide already in the atmosphere at any time, a change of a few percent in either the photosynthetic or the respiratory flux would soon significantly alter the atmospheric carbon dioxide content. Will global warming produce such an imbalance?

The answer is unclear and probably will remain so until after the climate has changed considerably more than it has already. Nevertheless, the general picture is probably as follows. The rate of photosynthesis is affected by many factors, particularly the availability of light, water and nutrients. It is not, however, very sensitive to temperature change. The rates of plant respiration and decay, on the other hand, do strongly depend on the temperature. A one-degree temperature change in either direction often alters rates of plant respiration by from 10 to 30 percent.

These observations suggest that a global warming will speed the decay of organic matter without appreciably changing the rate of photosynthesis. That will increase the release of carbon dioxide into the atmosphere. A warming will also result in more methane, because methane is produced by respiration in regions where oxygen is not freely available, such as swamps, bogs and moist soils. In recent years there has been a rise in the concentration of atmospheric methane of more than 1 percent per year. The increase is both rapid and significant because, as noted above, methane is 20 times as effective as carbon dioxide in trapping heat. The wet soils where methane is produced as a result of anaerobic decay probably represent the world's major source of methane. The global warming that has already occurred has undoubtedly stimulated anaerobic decay and the production of methane as well as carbon dioxide.

It is possible to estimate the size of the resulting increase in carbon production at least crudely. A significant fraction (from 20 to 30 percent) of global respiration on land takes place in the forest and tundra of the middle and high latitudes, where the warming is expected to be greatest. If we assume that the mean global warming to date has been .5 degree C, and that in the middle and high latitudes the rise has been one degree, then plant respiration in these latitudes and the decay of organic matter in soils has increased significantly. If the increase in respiration is between 5 and 20 percent over 20 to 30 percent of the total area respiring, then total global respiration will increase between 1 and 6 percent above normal. Once again assuming that the annual flux of carbon into the atmosphere is 100 billion tons and that the rate of photosynthesis remains unchanged, the warming that has already taken place has meant an injection of between one and six billion tons of carbon per year. Over the past century from 20 to 30 billion tons of carbon may have been released in this manner.

That estimate is probably high, because the average warming may have been less than assumed and because photosynthetic response will tend to reduce the release of carbon dioxide. Yet the estimate is probably not high by as much as a factor of two, and it serves to emphasize the importance of biotic feedback mechanisms.



RHÔNE GLACIER in Switzerland is shown in a lithograph after an 1848 watercolor by Henri Hogard (*top*). Four sets of moraines are clearly visible. The outermost set has been dated to 1602, the second to 1818, the third to 1826 and the fourth to 1848; the pattern indicates that the glacier had been retreating up the valley for at least 250 years. A photograph from 1970 (*bottom*) shows that the glacier has retreated still farther up the valley. The retreat is additional evidence for recent global warming.

How does the value just computed compare with amounts of carbon released by other known processes? The release from the burning of fossil fuels is approximately 5.6 billion tons per year; deforestation adds an amount estimated at between .4 and 2.5 billion tons per year. The total carbon injected into the atmosphere from these two sources added to a temperature-enhanced respiration is not known, but it appears to be more than six billion tons annually and may approach 10 billion.

The release of carbon due to changes in the respiratory rate could fluctuate appreciably; a gradual warming, such as that experienced over most of this century, would change the respiratory rate slowly enough so that year-to-year changes would be inconspicuous. On the other hand, a sudden warming or cooling over a period of several years might result in an observable change in the carbon dioxide content of the atmosphere. In the past 15 years the annual rate of accumulation of atmospheric carbon dioxide has been about 1.5 parts per million, equivalent to a global accumulation of about three billion tons of carbon.

According to data recorded on Mauna Loa and at the South Pole by Keeling, however, over the past 18 months the accumulation rate has risen to about 2.4 parts per million, equivalent to about five billion tons of carbon. Keeling expects that the surge will prove transitory, as a lesser surge in 1973 and 1974 did. Nevertheless, the implication we assign to the observations at the moment is that the surge is a result of the high temperatures that have marked the 1980's, delayed by the time necessary to warm the soil. Whether this interpretation is correct remains to be seen.

Any climatic change can also be ex-

"GLOBAL WARMING FLOODS FLORIDA" could be a tabloid headline if the polar ice caps began to melt. Florida is shown here as it might look if sea level rose 4.6 meters above (*bluish green*) or 7.6 meters above (*light green*) the present level (*blue*). In either case Miami and Lake Okeechobee are submerged. A rise of four to five meters might be expected if the West Antarctic Ice Sheet broke up under global warming.

pected to affect the ability of the terrestrial biota, in particular forests and soils, to retain carbon. At warming rates that are lower than the rates at which forests develop, forests may actually expand, and with them the capacity to store carbon. But if the warming rate exceeds the rates at which forests migrate into more climatically favorable regions, widespread mortality of trees and other plants is likely to follow. The net result of such destruction of forests is difficult to predict, but it will probably mean a further release of carbon dioxide through the decay of plants, animals and organic matter in soils.

The amount of carbon dioxide that could be injected into the atmosphere would depend heavily on the rate of climatic change in the forested zones of the middle and high latitudes. Although it is impossible to make any accurate calculation, an upper limit is given by the amount of carbon in these forested latitudes: approximately 750 billion metric tons, or about the same amount of carbon as there is in the atmosphere currently.

Is it possible that a global warming could stimulate the growth of forests? In this case the spread of forests to high latitudes and tundra regions would result in a greater uptake of carbon dioxide from the atmosphere and a greater accumulation of carbon dioxide in the soil. Such a transition is unlikely. Forests require centuries to develop, especially where soils are thin and nutrients are in short supply. They also require climatic stability and sources of seeds. The climatic transitions currently under way, unless they are checked, are rapid by any measure and can be expected to continue into the indefinite future. They do not offer the conditions under which forests are able to develop on new land and remain for long periods.

Might the warming at least stimulate existing forests to store additional carbon in plants and soil? Perhaps. The boreal forest and other coniferous forests may indeed be sufficiently resilient to respond to warming with increased photosynthesis and growth. Whether the carbon taken up by photosynthesis will be stored or simply released through increased respiration remains an open question.

There is also the possibility that the tundra, the treeless plain found in arctic and subarctic regions, will respond to a warming in surprising ways, including an increase in the production of carbon and its storage in

peat. The nature of the response will largely hinge on the availability of water. A wetter tundra might store additional carbon in soils; a drier tundra might release it through the decay of organic matter in long-frozen soil or soil that is normally frozen for most of the year. W. Dwight Billings of Duke University believes global warming will speed the decay of peat in tundra soils and precipitate that ultimate breakdown of the tundra known as thermal karst erosion, which allows flowing water to erode the tundra in great acre-size chunks. Not only is the tundra devastated but also substantial amounts of carbon dioxide and methane that were stored in the peat as carbon are released into the atmosphere.

The evidence indicates that under rapid planetary warming respiration rates will increase more than photosynthesis rates. The changes will lead to the release of additional carbon dioxide and methane into the atmosphere. The magnitude of the release will hinge strongly on the rate of warming: the faster the warming, the larger the release. Such behavior is consistent with (but not proved by) the data from the Vostok core.

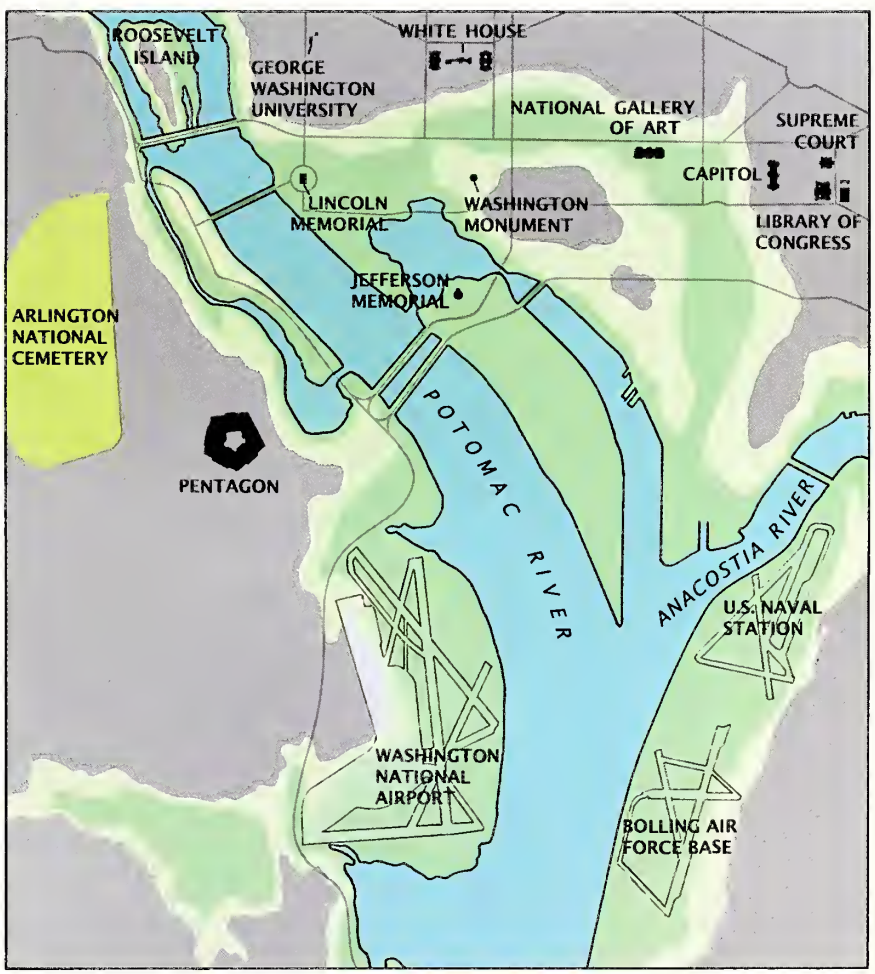
What will be the consequences of a continued global warming? In 1985 a group of meteorologists meeting under the auspices of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) demonstrated that without the respiratory feedback mechanisms addressed above, the combined effect of the greenhouse gases would warm the earth by an average of from 1.5 to 4.5 degrees C before the middle of the next century. The conclusion was recently confirmed in a review written by more than 50 scientists who met in Villach, Austria, in 1987 and was published by the WMO and the UNEP.

Seldom has there been such a strong consensus among scientists on a major environmental issue. The warming, unless consciously checked by human effort, will be rapid and will be felt differentially over the earth. Winter temperatures in the middle and high latitudes can be expected to rise by more than twice the world average. If the mean global temperature were to rise by from two to three degrees C by the year 2030, the winter temperature increase in Minneapolis might approach from four to six degrees C, or about one degree per decade. Summer temperatures would also rise, but less severely. A one-degree change in temperature is equivalent to a change in latitude of from 100 to 150 kilometers. The prairie-forest border, which is now south and west of Minneapolis, might be expected to migrate north at a rate of between 100 and 150 kilometers per decade, or between 400 and 600 kilometers by the year 2030.

Such changes are likely to be difficult for most of the world's peoples. First, the changes will be continuous. Unless the warming stops, efforts to adapt to climatic changes are likely to be responses to conditions that no longer exist. Second, the changes in climate will be irreversible for any time of interest to us or our children. There is no way to cool the earth or to lower sea level; we cannot return quickly to an atmosphere with lower concentrations of greenhouse gases. The best we can do is to reduce current emissions. If that step is taken immediately, a further warming of more than one degree can be expected as the full effects of the heat-trapping gases already present are felt.

Finally, the effects are open-ended. Although most modeling to date simulates a doubling of the atmospheric carbon dioxide content, there is simply no reason to assume that the concentrations will stop at twice the current levels. Estimated reserves of recoverable fossil fuels in themselves are enough to increase the atmospheric concentration of carbon dioxide by a factor of from five to 10.

Can anything be done to slow the climatic change that is now under way? The immediate need is to stabilize the greenhouse-gas content of the atmosphere. Regardless of its source, over the past decade carbon has been accumulating in the atmosphere at a rate of about three billion tons annually. (The remainder is being absorbed by the oceans or stored in forests and soils.) If current fluxes were reduced by three billion tons annually, the atmospheric carbon dioxide level would be stabilized for a few years. The stabilization would not



WASHINGTON, D.C., is depicted here under the same conditions as in the preceding illustration. Washington National Airport and the Lincoln Memorial are inundated. The 7.6-meter contour reaches almost to the Capitol steps and to the White House.

be permanent, however. The rate of accumulation in the oceans is determined by how fast they can absorb carbon dioxide from the atmosphere; this in turn depends on the difference in carbon dioxide concentration between the atmosphere and the ocean. As the flux of excess carbon is reduced, the difference is also reduced and the ocean becomes less capable of absorbing excess carbon; carbon dioxide emissions would have to be reduced still further to prevent additional atmospheric accumulation.

The largest source of carbon dioxide emissions is the combustion of fossil fuels, which releases about 5.6 billion tons of carbon into the atmosphere annually. Industrial nations contribute about 75 percent of these emissions; steps toward stabilizing the composition must begin in the industrialized world. A recent study carried out under the auspices of the World Resources Institute and led by José Goldemberg, president of the University of São Paulo in Brazil, suggests that the consumption of energy from fossil fuels in the developed nations could be halved by a program of conservation and improved efficiency alone.

Although developing nations produce less carbon dioxide, their contributions are growing; if economic development follows conventional patterns, their potential contributions are very large. The second step toward the stabilization of greenhouse gases will require innovations in economic development that lessen dependence on fossil fuels.

The other known major source of carbon dioxide is deforestation, predominantly in the Tropics. By 1980 about 11,000 square kilometers of forest were being cleared annually, with the result that in 1980 between .4 and 2.5 billion tons of carbon (as carbon dioxide) were released into the atmosphere. The rate of deforestation has increased over the past decade. If the present release of carbon is near the upper end of the above range, halting deforestation would reduce carbon emissions by the three billion tons per year needed immediately to stabilize atmospheric composition.

Reforestation will also help to stabilize the composition of the atmosphere. The reforestation of from one to two million square kilometers (about the area of Alaska) will result in the annual storage of one billion tons of carbon. Although this area is large and productive land in the Tropics is at a premium, there may be as much as 8.5 million square kilometers of once forested land available for reforestation. Of this land, about 3.5 million square kilometers could be returned to forest if permanent agriculture were to replace shifting cultivation. Another five million square kilometers of deforested land are currently unused, and there reforestation could in principle be implemented immediately. Forests established to store carbon would, of course, have to be maintained: neither harvested nor destroyed by toxic effects or change in climate.

Each of the measures to stabilize the atmospheric carbon dioxide level would have salutary effects locally, regionally and nationally, quite apart from its effects on climatic change. An improvement in energy-use efficiency, a step that might have been taken long ago with benefits to all, would bring economic and material advantages to both individuals and nations. An improvement in efficiency would lessen reliance on fossil fuels; this in turn would reduce sulfur and nitrogen oxide emissions, acid deposition and the release of other toxins. Halting deforestation would help to maintain the genetic diversity of the planet, reduce erosion, stabilize local and regional climates, cleanse water and air and preserve opportunities for future generations.

No one remedy by itself is likely to stabilize the levels of carbon dioxide and methane in the atmosphere. If the accumulation of carbon dioxide in the atmosphere persists, the carbon burden will have shifted from three billion tons annually to five billion tons and will be that much more difficult to address. The measures that are required can begin at home, although it is clear the world must join in the effort if it is to be effective. There are precedents for international action on similar issues. The Limited Test Ban Treaty of 1962 was an agreement among certain nations to avoid atmospheric tests of nuclear weapons. It has been effective. Nations that did not sign it (France and the People's Republic of China) have yielded to international pressure and now conduct weapons tests underground. The Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol, the latter negotiated in 1987, have moved the world far toward the elimination of chlorofluorocarbons.

There is no reason to assume that similar progress cannot be made with carbon-based fuels and deforestation. With that end in view a series of steps has already been undertaken: 50 specialists in international diplomacy and law met recently under the auspices of the Woods Hole Research Center to outline approaches that might work. The greatest problem is gaining the active and effective support of the developing nations, which are poised for a massive increase in fossil-fuel consumption. Development need not, however, follow historical paths. To cite one example, the low-latitude countries stand to gain immeasurably as techniques for exploiting solar energy are perfected. Solar-powered electrolysis of water can produce hydrogen, which in turn can run automobiles and other machinery. There are few places in North America where domestic hot water cannot now be produced by solar energy at little or no cost throughout most of the year. Nor is it to the advantage of nations to allow their forests to be destroyed.

Conferences are under way in the developing nations to explore alternatives to the present course. The first was held in New Delhi in February; the second is planned for São Paulo in September under the leadership of Goldemberg. The conferences will explore the possible responses of developing nations to a world in which conventional energy sources are limited. There are extraordinary opportunities for industrial innovations, particularly in energy efficiency and solar power. But developing countries cannot be expected to shoulder the entire burden; the developed nations, which are responsible for most of the problem, must do their share.

These issues will persist throughout the next century and dominate major technical, scientific and political considerations into the indefinite future.

FURTHER READING

GLOBAL DEFORESTATION: CONTRIBUTION TO ATMOSPHERIC CARBON DIOXIDE. G. M. Woodwell, J. E. Hobbie, R. A. Houghton, J. M. Melillo, B. Moore, B. J. Peterson and G. R. Shaver in *Science*, Vol. 222, No. 4628, pages 1081-1086; December 9, 1983.

THE FLUX OF CARBON FROM TERRESTRIAL ECOSYSTEMS TO THE ATMOSPHERE IN 1980 DUE TO CHANGES IN LAND USE: GEOGRAPHIC DISTRIBUTION OF THE GLOBAL FLUX. R. A. Houghton, R. D. Boone, J. R. Fruci, J. E. Hobbie, J. M. Melillo, C. A. Palm, B. J. Peterson, G. R. Shaver, G. M. Woodwell, B. Moore, D. L. Skole and N. Myers in *Tellus*, Vol. 39B, Nos. 1-2, pages 122-139; February-April, 1987.

GLOBAL TRENDS OF MEASURED SURFACE AIR TEMPERATURE. James Hansen and Sergej Lebedeff in *Journal of Geophysical Research*, Vol. 92, No. D11, pages 13345-13372; November 20, 1987.

Overview of Global Environmental Change: The Science and Social Science Issues

PAPER

ABSTRACT

Among the many problems that the environment now faces, global warming due to our relentless burning of fossil fuels and the resultant greenhouse effect must rank at the top. The basic cause is, of course, humanity's need for energy, and currently about 80 percent of the energy we generate comes from fossil fuels (coal, petroleum, and natural gas). While a general warming trend may not be too serious by itself, it will be the accompanying shifts of rainfall and snowfall patterns, the gradual rise of sea level, the forced migration of ecological systems such as forests, and so forth, that will challenge the resourcefulness and resiliency of future generations. If we could predict exactly how these climate changes will evolve, we could be better prepared. The system that determines our climate is very complex, however, and our climate models cannot simulate it adequately, especially on a regional scale. There will be many readjustments required of mankind, and a basic imperative must be the slowing of the explosion of the population of the human race.

William W. Kellogg
Senior Scientist (Retired)
National Center for Atmospheric Research
Boulder, Colorado

INTRODUCTION TO THE GREENHOUSE EFFECT

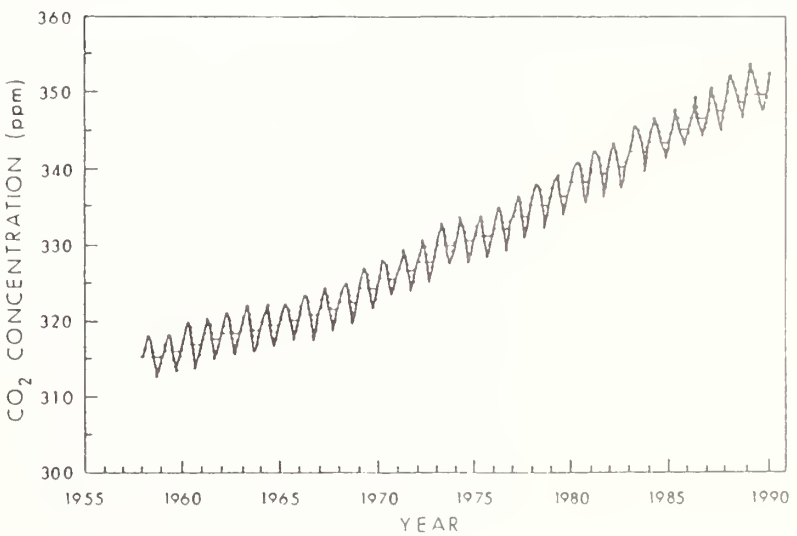
My particular interest for the past decade or more has been in the question of whether or not mankind is affecting the climate of the earth. We are changing the climate because we are changing the composition of the atmosphere, and this is in turn because we are putting enormous amounts of carbon dioxide into the atmosphere every year by burning fossil fuels. The amount is now up to nearly 6 billion tons of carbon in the form of carbon dioxide every year. The rate at which we burn fossil fuels has been steadily increasing since 1951, when the United Nations started to obtain good data on what the world was doing with its fossil fuels. From 1951 to 1973 the carbon dioxide increase had been approximately 4 percent per year, which is exponential growth with a doubling time of only fifteen years. In 1973 the OPEC oil embargo and a worldwide recession slowed the increase of fossil fuel use to approximately 2 percent per year, but that rate still has a doubling time of about thirty-five years.

We continue to increase the rate of use of fossil fuels, and in the developing world, it is going up by nearly 5 percent per year. However, in the industrialized world it is generally leveling off, even in the United States. (The exception in the United States is the increasing use of automobiles and the consequent continued increase in consumption of gasoline.) Some countries, notably Sweden and Germany, are actually decreasing their use of fossil fuels. With this being the case it is not surprising that carbon dioxide concentration is increasing in the atmosphere, a fact that we can see from the record at the Mauna Loa Observatory (Figure 1), the Point Barrow record, the American Samoa record and the South Pole station record. They all show the steady increase in concentration of carbon dioxide and of some other gases like methane and the chlorofluorocarbons.

The reason for concern is that carbon dioxide is one of the greenhouse gases. The greenhouse theory is an old theory. Jean-Baptiste Joseph Fourier in France talked about the greenhouse theory at the turn of the nineteenth century, shortly after the French Revolution. He had an idea that the atmosphere must be like a giant greenhouse, "un effet de verre," he called it, being a Frenchman, and since then various people have made calculations about how much of a warming would take place if we increased these greenhouse gases.

The greenhouse gases warm the earth in the following manner. The sun shines down and warms the earth's surface—there is actually very little absorption of sunlight in the atmo-

FIGURE 1. Concentration of carbon dioxide in the atmosphere from 1958 to mid-1990, measured at the Mauna Loa Observatory on the Island of Hawaii. The annual changes are due to the respiration of plants in the Northern Hemisphere. This set of measurements, made by C.D. Keeling of the Scripps Institution of Oceanography, is the longest continuous record, but there are now similar records from Point Barrow, Alaska, to the South Pole. (Source: IPCC, 1990).



sphere if no clouds are in the way. Obviously, the surface does not become increasingly warmer. Energy is dissipated as the surface reradiates the heat received from the sun but in a different part of the spectrum, in the infrared part of the spectrum.

Infrared radiation is the radiation that can be felt when approaching a hot stove. In fact, a former name for it was "heat radiation," since it could be felt but not seen. This infrared radiation is absorbed by carbon dioxide, by water vapor, by methane and by many other trace gases. These gases are called "greenhouse gases" because they block some of that infrared radiation from escaping to space, thereby acting like the glass of a greenhouse. The more the greenhouse gases block the infrared radiation, the warmer they keep the surface. So if we add more of those infrared absorbing gases to the atmosphere, it increases the greenhouse effect and warms the world still more. We have, in fact, already warmed the earth. Since 1900, the global average temperature, measured both at land stations and by ships at sea, has gone up by about 0.6 degrees centigrade. (If you like Fahrenheit degrees better, just double the numbers.)

Six tenths of a degree centigrade may not sound considerable, but it actually turns out to be quite significant. In the climate record that has been reconstructed for the past many thousands of years, there does not appear to be any other time when such a rapid change occurred over a period of only 100 years. When the earth came out of the last Ice Age 18,000 years ago, there was a bigger change (several degrees in going from an Ice Age into an interglacial period, such as we are in now) but that took many thousands of years to occur. Now, in just one century, we are causing 0.6 degree centigrade warming. The decade of the 1980s has had six of the warmest years on record and 1990 set still another new high.

SOME QUESTIONS ABOUT THE THEORY

As you probably have already gathered, I am fairly convinced that the greenhouse effect is here, but some of my colleagues are reluctant to admit that it is. They have various reasons for doubting the astonishing idea that mankind is warming the earth. I think that, even though scientists are supposed to be open-minded and objective, there sometimes enters a sort of "tribal guilt" on the part of some scientists who just do not want to believe that mankind can tamper with nature to that extent. They do not use that phrase, "tampering with nature," but I think this thought may be in the back of their minds.

The much more legitimate reason for doubting that mankind is actually warming the earth is simply a product of the scientific method that encourages scientists to criticize and carefully analyze any new idea. Some scientists are just not ready to accept the idea that there is enough information about this very complicated climate system to say that the greenhouse effect is being enhanced.

As an advocate of the greenhouse warming idea, I have been collecting intriguing statements, mostly from the popular press, which express the feeling that there is something wrong with this proposition that we are warming the earth (Kellogg, 1991). Here are a few of the reasons that they propose. The headlines in the distinguished *New York Times* a couple of years ago announced that a very reputable climatologist from the National Oceanic and Atmospheric Administration (NOAA) and some of his colleagues had found that, looking at the United States climate record, there was no sign of any greenhouse warming. No doubt he knew what he was talking about, but notice that it was simply an analysis of the temperature record of the stations in the lower forty-eight states. The United States occupies quite a bit less than 5 percent of the area of the globe, so what happens in the United States is not necessarily going to apply to the rest of the world, particularly to the oceans. What has actually happened in the continental United States is that the western part of the country has warmed up and the eastern part has cooled off slightly. The net effect has been little or no change in the United States.

Some also point to evidence that the North Atlantic and North Pacific oceans are both cooling, so they conclude that global warming is not taking place. It is true that the North Atlantic, and even more so the North Pacific, have actually become colder in the past twenty years.

To see if we can explain this rather surprising behavior, let us look at a recent experiment where the carbon dioxide, or the greenhouse effect, was gradually increased in the National Center for Atmospheric Research (NCAR) climate model with a circulating ocean (Washington and Meehl, 1989). Such a model of the earth's climate system is a theoretical program that tries to take into account as many of the factors that govern our climate as human ingenuity and computer speed will allow. It is essentially a set of mathematical equations that can be solved on a large computer. In the case of the NCAR model there was both a circulating global atmosphere and a circulating ocean underneath. In years 26 to 30 of the experiment (years of model time), the following occurred in this climate model: during the wintertime there was a big increase in temperature over North

America and over Eurasia. However, the North Atlantic cooled, and the North Pacific also cooled, but to a lesser extent; during the summer the effect was less pronounced.

These occurrences can be explained by studying what happened in the model and also what has been happening recently in the real atmosphere and ocean. The warm Gulf Stream was pushed a bit further south because prevailing winds came more from the northwest than from the west, and by the same token, the cold air flowing over the North Atlantic cooled the North Atlantic. So both the ocean and the atmosphere provide an explanation for the fact that, even though the overall radiation change was leading to a warming, the net effect in the North Atlantic was a cooling.

These are just two examples of what some scientists have been invoking to try to show that the greenhouse warming idea is wrong. These scientists have been called "the environmental naysayers," and in a recent article (Kellogg, 1991) I discuss these skeptical statements—statements that are either misleading or just plain wrong, in my opinion. Naysayers believe we should not make any policy decisions until we have done much more research. That is a typical response of politicians who do not want to do anything about climate change or acid rain or any other environmental problem.

ATMOSPHERIC CHANGES CAUSED BY MANKIND

What has been said so far is an introduction to the subject of the greenhouse effect and global warming, and some of the things that skeptics, or naysayers, are saying to discredit the notion. Let us now turn to some further facts in the matter to gain a better understanding of what changes mankind is causing on Planet Earth.

I have mentioned that the concentration of carbon dioxide in the atmosphere is increasing. According to the famous Mauna Loa Observatory record on the island of Hawaii, the level of carbon dioxide in the atmosphere has been steadily climbing since recordings at that site began in 1958 (Figure 1). It has increased by nearly 30 percent since the start of the Industrial Revolution and the beginning of extensive burning of fossil fuels. It is currently rising by about 0.5 percent per year.

The concentration of methane, another infrared absorbing gas, is rising at about 1 percent per year. This increase does not come from fossil fuel burning, but is due to agriculture and other kinds of human activities like pipeline leaks and landfills.

The chlorofluorocarbons (CFCs), which are most notable because of their effect on the ozone layer, are increasing 3 or 4 percent per year, in spite of the fact that the United States and most of the industrialized countries have banned chlorofluorocarbons in spray cans. They are still being used in refrigerators and air conditioners, however, and less developed countries, including China and India, are still using chlorofluorocarbons in spray cans. The CFCs are extremely effective greenhouse gases. Table 1 summarizes the main facts about the greenhouse gases that have been mentioned and some other trace gases that also contribute to the anthropogenic global warming. Much more information about these gases and their sources and sinks can be found in the report of the International Panel on Climate Change (IPCC, 1990).

TABLE 1. The greenhouse gases.

	Relative Contribution to Anthropogenic Greenhouse Effect Now (%)	Approximate Lifetime in Atmosphere (yrs)	Annual Rate of Increase (%)
Carbon Dioxide CO_2	60	50–200	0.5
Methane CH_4	15	10	0.9
Chlorofluorocarbons CFCs	12	60–100	4
Nitrous Oxide N_2O	5	150	0.3
Tropospheric Ozone O_3	8	weeks	0.5–2.0

IS PAST GLOBAL WARMING SIGNIFICANT?

The greenhouse theory has already been explained, and it predicts that an increase in the greenhouse gas concentration should cause global warming. Indeed it has, but there is some question about how significant the 0.6 degree centigrade rise in temperature really is. Could it be due to just chance, to some combination of random temperature fluctuations?

If you use a statistical signal-to-noise argument, the "signal" that we have seen is the 0.6 degrees centigrade; the "noise" is a measure of the random fluctuations, and it is 0.2 degrees centigrade. Therefore, there is what the communications people call a "signal-to-noise ratio of 3." Applying a short statistical test, we then say that the probability of that signal being real, and not just an artificial product of the noise, is more than 99 percent. In other words, there is a 99 percent probability that the signal is real and not just a product of the noise.

Dr. James Hansen, the director of the

NASA Goddard Institute for Space Studies in New York was testifying before Congress in the fall of 1988, and the Senators and Congressmen were asking him whether he believed that climate change was taking place. He is paraphrased as having said, "Yes, I think that, with about a 99 percent probability, the climate warming is occurring." He may have been drawing on a report of the World Meteorological Organization made several years earlier (WMO, 1982), where that same argument was being used. By the way, many skeptics criticized Hansen for declaring that global warming had a 99 percent probability of already having taken place (but I agree with him).

Let us hasten to add, however, that the climate change theory still has some substantial unknowns. For example, it cannot take into account changes in solar input; we know our sun is a slightly variable star. It cannot take into account changes in the ocean circulations; the more oceanographers look into this question, the more they realize that the ocean has recently had some relatively big changes in its circulation, all of which can affect the year-to-year temperature of the globe (this will be discussed in greater detail below). Furthermore, scientists are not satisfied that they are taking cloudiness into account properly in theoretical climate models. So it really should not surprise us that such a complicated system does not follow a simple, smooth increase due to the greenhouse effect. The point is that there are surely many other happenings that we cannot take fully into account.

To pursue that matter a bit further, we can be quite sure that there will be surprises in store for the world. There are dramatic and sudden changes in the past climate record that can be only partially explained, and those explanations almost invariably involve the oceans and their circulations. I have already mentioned the curious fact that, while most of the world has been warming, in the past two decades or more the surface waters of the North Atlantic and the North Pacific have been getting cooler as a result of circulation changes.

Oceanographers have been fascinated by a conjecture concerning the exchanges of surface water with the cold deep water. Henry Stommel many years ago described a three-dimensional ocean circulation pattern that has since been termed "the conveyor belt," since it accounts for the centuries-long transport of water horizontally between the oceans and vertically between the surface and the depths. Concentrating on just one part of the global oceanic conveyor belt, a major downwelling or sinking of surface water is thought to occur in winter north of Iceland in the Greenland Sea. This downwelling takes place as relatively saline Gulf Stream surface water is cooled and becomes more dense than the underlying water, and the result is convective overturning. Actually, this is not a conjecture any more since the tritium and other radioactive elements from the nuclear tests of the late 1950s and early 1960s have been observed to be slowly working their way southward in the depths of the North Atlantic, following more or less the path outlined by Stommel (Baes et al., 1985).

The aspect of this exchange that is most pertinent to the question of the greenhouse warming is that it is presumably this downwelling of surface water that transports some carbon dioxide-rich water downward, which allows the ocean to take up more of the added carbon dioxide from the atmosphere. (For the past three decades or more a little less than half of the annual addition of fossil fuel-produced carbon dioxide has been removed from the atmosphere by the oceans.) After all, the deep ocean, which stores at least sixty times more carbon dioxide than the atmosphere, must be the ultimate sink for the carbon dioxide produced by mankind.

Returning to the question of surprises, it has been suggested by several oceanographers that warming of the Arctic Ocean could result in more low-salinity water flowing northward into the Greenland Sea, and this stream of less dense water would inhibit the more saline Gulf Stream water from flowing southward into the Greenland Sea. The result, if this did happen, would be something like the following: The region where the downwelling has taken place in the past would be covered by less dense surface water. Therefore, the ocean would be stably stratified and there would be less overturning and downwelling in winter. This would cause a slowing of the conveyor belt circulation, and slower removal of the added industrial carbon dioxide from the atmosphere. This is known as a "positive feedback" since the greenhouse warming would result in more carbon dioxide remaining in the atmosphere, and hence, an even stronger greenhouse effect.

Again, this is not just conjecture about the future. Observations of the composition of bottom water in the Greenland Sea strongly suggest that the formation of new Greenland Sea deep water has slowed appreciably in the past decade (Schlosser et al., 1991). The above could provide at least part of the explanation for this remarkable but little noticed change in the ocean. It might also partly explain why there has been a more rapid increase in the atmospheric concentration of carbon dioxide in the past several years, jumping from a long-term rate of increase of about 0.3 percent per year to about 0.5 percent per year (Keeling, private communication).

THOUGHTS ABOUT THE FUTURE

If I were to make a guess about the future, I would say that by the middle of the next century we may have a doubling of the greenhouse gas concentration over its level in the mid-nineteenth century. As a result, the global warming models project a two to five degree centigrade global average temperature rise and two or three times more than that in the Arctic. These projections are shown in the far right of Figure 2. The shaded area indicates what I think will be the change in the temperature. The high scenario depends on whether we continue to burn fossil fuel at an increase of 2 percent per year, and the low scenario assumes that the world takes effective actions to limit it. These numbers are close to those adopted recently by the Intergovernmental Panel on Climate Change (IPCC, 1990).

This is not just a problem in geophysics. It is also a problem in economics and political science (Kellogg and Schware, 1982). It is indeed difficult to forecast what mankind will decide to do, and those actions will depend on the development of new technologies, such as more efficient use of energy, adoption of new nuclear generators, and a slowing of the present growth of the world population.

What does a global warming mean in human terms? It means many different things, of course. Consider Figure 3, where the shaded area on the map shows where the average temperature is between 2 degrees centigrade and 18 degrees centigrade, with an average of about 10 degrees centigrade. Geographers and anthropologists call this area "the comfort zone." When I first heard that expression I found it amusing, because people who live in the comfort zone often choose to vacation in the tropics if they can afford it. The comfort zone is where most of the wealthy and industrialized countries are located, and in between the two shaded areas is the great area of the tropics where most of the poor countries exist and where there are problems with tropical diseases and famine. Presumably this comfort zone would migrate poleward as the world warms.

However, even more important than temperature changes will be moisture changes. Rainfall has been changing in the past couple of decades at the same time the temperature has been changing, which is not surprising. If we look at the subtropics in the Northern Hemisphere (between 5 and 35 degrees north latitude), the annual rainfall has been decreasing since about 1955, but in the more northern part of the Northern Hemisphere (35 to 70 degrees north), it has been increasing. Thus, while the higher latitudes have become wetter, the equatorial zone has become drier.

FIGURE 2. Past and future globally averaged temperature and estimated polar regions temperature. The dashed line indicates the temperature record that might have taken place if there had not been any greenhouse warming. The vertical bars indicate the range between a "high" and a "low" scenario of fossil fuel use. This temperature scenario assumes that doubling of the greenhouse gases will occur about 2050 A.D. for the dotted "estimated temperature" curve, but it could be later or earlier depending largely on the rate of fossil fuel use.

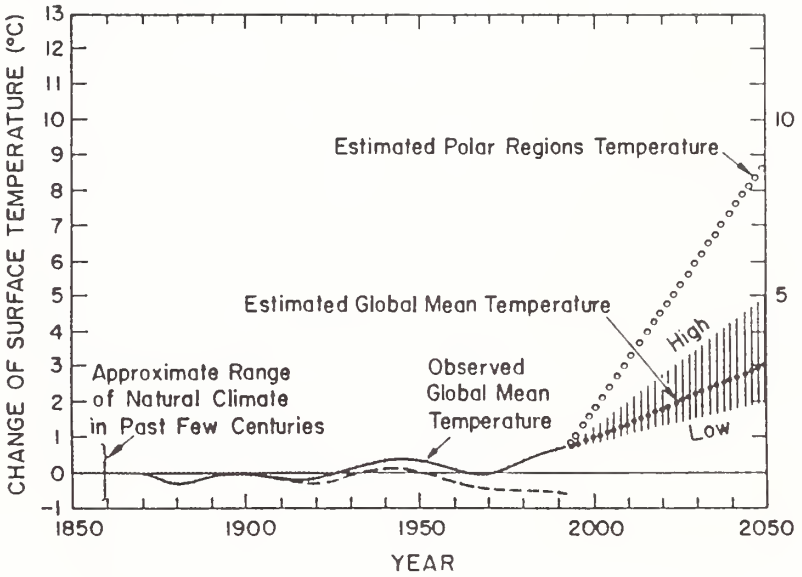
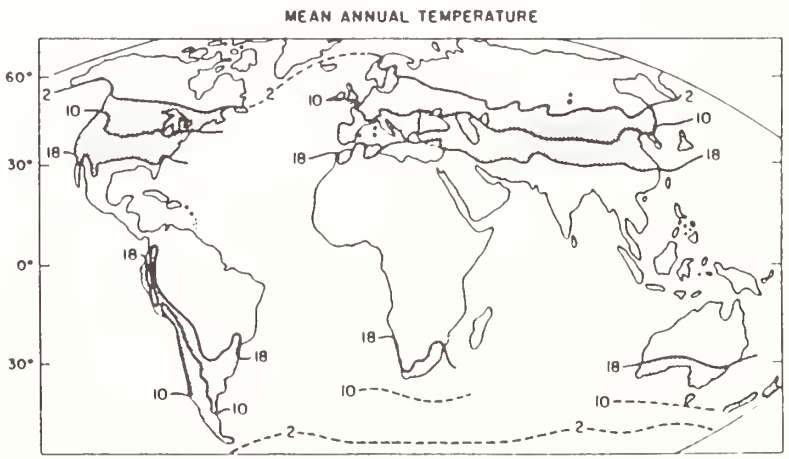


FIGURE 3. The so-called "comfort zones" (shaded areas), where the mean annual temperature lies between 2°C and 18°C. This is where the maximum demand for space heating occurs. It is also the part of the world where most of the industrialized nations lie. (Source: McKay and Allsopp, 1980).



Our model experiments show that central North America may expect a drying out in the summer, and the same may be true in central Eurasia (Figure 4). A midwest farmer does not need to be convinced of that idea; he knows that a warm summer is likely to be a dry summer.

The same thing may not necessarily be true in the winter. Our climate models show that, if anything, the winters in most of North America will be wetter. That is reassuring, because it suggests that the farmers in the mid-

west can switch from corn, which takes a lot of water in the summer, to winter wheat, for example. That is one of the ways these farmers may be able to adapt to the climate change.

It is interesting to note that the subtropics may become wetter according to the models, but in the past several decades, as I mentioned, the subtropics in the Northern Hemisphere have actually been getting drier. Does this suggest, perhaps, that the tropical drying trend is going to stop and rainfall will go back up again? It is too soon to make any prediction, but we can hope that this will happen for the sake of those in famine-prone North Africa and northeast Brazil.

We are now in a period when climate models are far from representing the real climate system, although they are the best tools available for forecasting the future. The important point to keep in mind is that we have to take the model forecasts with caution. Also, while they are fairly capable of depicting the global scale, they are not at all reliable in showing regional climate changes.

FIGURE 4. Example of a scenario of possible soil moisture changes on a warmer Earth. It is based on paleoclimate reconstructions of the Altithermal Period (4,500 to 8,000 years ago), comparisons of recent warm and cold years in the Northern Hemisphere, and several climate model experiments. Where there is agreement between two or more of these approaches on the direction of the change, the area of agreement is indicated with a label surrounded by a dashed line. (Source: Kellogg and Schware, 1982).

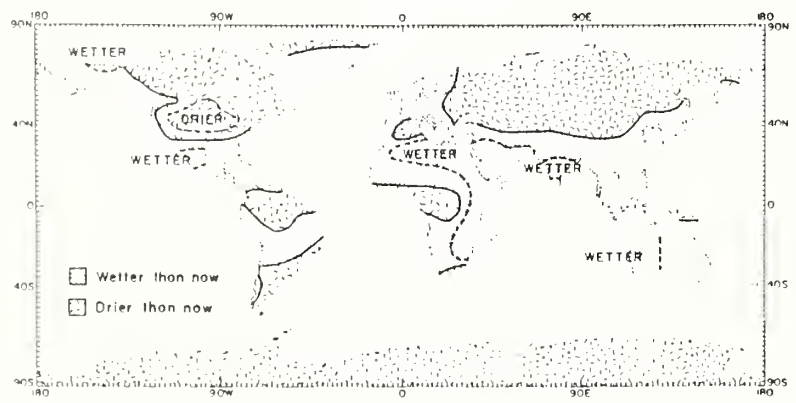
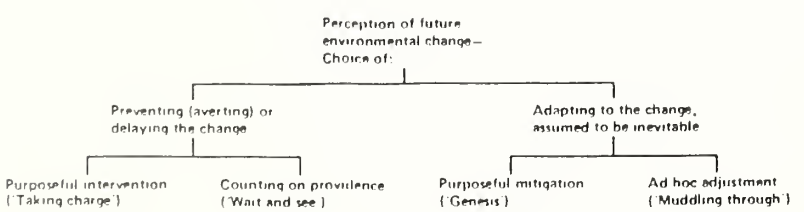


FIGURE 5. A decision tree showing the range of choices that could in principle be made in order to cope with climate change. The actions on the left would presumably have to be taken on a worldwide basis to be effective (see text), but those on the right can be taken at any level of society



POSSIBLE ACTIONS TO TAKE

Let us now turn to the question of what to do about the situation. There are several courses of action, as shown in Figure 5, that can be taken. Assuming that there is going to be a serious global warming, the world could take action and prevent the environmental change. To do this we would have to cut out or at least greatly reduce fossil fuel burning. Obviously, we are not going to eliminate fossil fuel burning right away. The industrialized world could not possibly do that, although several countries are now urging the rest of the world to agree to at least limiting the use of fossil fuels. That would presumably require some governmental action. Germany, Sweden, France, Italy, Holland, and even England and Japan are urging that we cut back on the use of fossil fuels by being more efficient. They have good reason to think that being more efficient would actually be economically sensible. Being more efficient would not be a hardship in the long run, they argue. For example, if the United States imposed a dollar a gallon tax on U.S. gasoline sales, some people would say that was a hardship. But it might cut back enough on driving so that we would not have to import oil from the Middle East, which would be to our advantage. That is the kind of tradeoff that is involved when one begins to think about the longer term future.

While a "muddling through" is probably the most likely course (as shown at the right of Figure 5), a better course is to accept the notion that climate change is more or less inevitable and then to prepare for it. My colleague Stephen Schneider called it the "Genesis Strategy," based on the story of Joseph in Egypt (Schneider, 1976). You will remember that the Old Testament credits Joseph with making the first accurate climate forecast, and he persuaded the Pharaoh to store the wheat of Egypt during the plentiful years so that they had some during the following seven years of famine. The Genesis Strategy makes good sense for a number of reasons.

Here are some of the measures that might be taken to increase our ability to get through a climate change (Kellogg and Schware, 1982). We might protect arable soil, improve water management, and apply agro-technology, that is, develop other strains of crops and trees that will grow in the new climate. We could improve coastal land-use policies, recognizing that sea level is likely to rise. The last blue ribbon committee report considering sea level forecasted that it could rise about a third of a meter by the middle of the next century (IPCC, 1990). That is enough to cause some trouble along seacoasts everywhere.

Then, of course, to slow the climate change, energy conservation should be a number one priority since this would reduce the consumption of fossil fuels and the release of carbon dioxide. Part of any energy conservation strategy would be to develop renewable resources, these being various forms of solar energy, hydropower, geothermal, and (yes) nuclear electricity generators.

Under the Reagan administration, our federal investment in solar energy and other renewable energy resources almost came to a halt, although now there is some federal money going back into it. The argument was that if solar energy is such a good thing, then industry should sponsor the research and development involved. Actually, industry did this to some extent. For example, the efficiency of the thin photovoltaic films that convert solar energy directly to electricity has increased by about a factor of ten in the last ten years, and they have become cheaper, too. I think that in the next decade, electrical energy will be generated from the sun competitively with fossil fuels, and this will be a big step forward.

So that is where we stand, with the European countries and Japan wanting to agree to slow the use of fossil fuels, the United States, China, Russia, India, and most of the Third World countries not willing to agree. In 1992 there will be a major United Nations sponsored international meeting in Rio de Janeiro on the environment and development, and we will see then if the beginning of an international agreement or protocol can be adopted that would effectively slow the worldwide use of fossil fuels.

One cannot leave this enormously important and complex subject without emphasizing that the basic worldwide environmental problem is *too many people*. The human population of the planet is still increasing at several percent per year, with the greatest growth being in many of the poor countries of the Third World that cannot feed and clothe their people now. The pressure of human activities on the global environment cannot be relieved if the population continues to soar upward. That is surely our major challenge, now and in the years ahead.

REFERENCES

Baes, C.F., Bjorkstrom, A. and Mulholland, P.J. 1985. Uptake of carbon dioxide by the oceans. Chapter 5 In: *Atmospheric Carbon Dioxide and the Global Carbon Cycle*. J.R. Trabalka (ed.) U.S. Dept. of Energy rept. DOE/ER. 0239, Washington, D.C. pp. 81–111.

IPCC. 1990. Climate Change: The IPCC Scientific Assessment. Report prepared for IPCC by Working Group 1, J.T. Houghton, G.J. Jenkins, and J.J. Ephraums (eds.) Cambridge University Press.

Kellogg, W.W. 1991. Response to skeptics of global warming. *Bul. Amer. Meteorol. Soc.*, 72:499-511.

Kellogg, W.W. and Schware, R. 1982. Society, science, and climate change. *Foreign Affairs*, 60:1076-1109.

McKay, B.A. and Allsopp, T. 1980. The role of climate in affecting energy demand/supply. In: *Interactions of Energy and Climate*. W. Bach, J. Pankrath, and J. Williams (eds.) Reidel, Dordrecht.

Schneider, S.H. (with L.E. Mesirow). 1976. *The Genesis Strategy*. Plenum Press, New York.

Schlosser, P., Bonisch, G., Rhein, M. and Bayer, R. 1991. Reduction of deepwater formation in the Greenland Sea during the 1980s: Evidence from tracer data. *Science*, 251:1054-1056.

Washington, W.M. and Meehl, G.A. 1989. Climate sensitivity due to increased CO_2: Experiments with a coupled atmosphere and ocean general circulation model. *Climate Dynamics*, 4:1-38.

WMO. 1982. Report of the JSC/CAS Meeting of Experts on Detection of Possible Climate Change (Moscow, October 1982). World Climate Programme No. 29, prepared by W.W. Kellogg and R. Bojkov, World Meteorological Organization and International Council of Scientific Unions. Geneva, Switzerland.

A Character Sketch of Greenhouse

by Dr. David Rind

Reproduced by the National Agricultural Library from *EPA Journal* (January/February 1989).

The Greenhouse Effect has caught the imagination of the general populace in the last decade. What's more, the respected, generally conservative scientific establishment has become associated with relatively dire predictions of future climate changes the Greenhouse Effect may cause.

But how much do we actually know about the Greenhouse Effect? Can we really establish how much the climate will change, and when? Perhaps by separating the "hard" science—that which can be verified and is considered well-understood—from scientific theory or estimates, we can investigate the likelihood of near-term climate changes that have been projected. The series of questions which follow will help us explore what we currently know, or think we know, about the Greenhouse Effect.

Question: Do we really understand the "Greenhouse Effect"?

The "Greenhouse Effect" is the name for the physical process whereby energy from the sun passes through the atmosphere relatively freely, while heat radiating from the earth is partially blocked or absorbed by particular gases in the atmosphere. Because the sun is warmer than the earth, its energy is radiated at a higher frequency which is not absorbed well by gases such as carbon dioxide (CO_2) or water vapor In contrast, these triatomic gases (gases with three atoms per molecule) are effective absorbers of the lower-frequency energy radiated by the earth. Since the gases responsible for this selective absorption make up only about one percent of the atmosphere, they are known as "trace" gases. In general, we can calculate very accurately the energy absorbed by different gases, although there are some uncertainties, and when the concentration of a gas changes, we know how much more energy is being absorbed. This additional absorption by itself warms the planet: for example, doubling the concentration of CO_2 in the atmosphere would eventually lead to a global air temperature increase of 1.2^0 Centigrade (C)—about 2.2^0 Fahrenheit (F)—if there were no other changes in the climate system.

However, what we do not know is exactly how the rest of the system will react. The current numerical computer models of the earth's climate predict that the warming due to the increase in CO_2 will lead to more evaporation of water vapor from the ocean. Water vapor itself is a "greenhouse" gas, so as its concentration increases in the atmosphere, the planet will warm even further. With rising temperatures there will be less snow and ice to reflect energy from the sun back to space (snow and ice are very good reflectors). This promotes further warming because more of the sun's heat is retained in the earth.

These are examples of "positive feedbacks" in which the system responds to a warming climate with changes which amplify the warming even further. Both of these system responses are very likely to occur, although we cannot be sure of the magnitude of the changes. The models also predict cloud cover changes that will provide even more warming, but clouds are not modeled in a very sophisticated way because they are not well understood. Thus, the likely impact of cloud cover changes is quite uncertain.

The net result of these different processes in the various models is the tripling of the warming caused by the doubled CO_2 levels alone, producing a total warming of about 4^0 C (or 7^0 F) for the global, annual average. Yet it is only the initial Greenhouse Effect due to increased CO_2 or increases in other trace gases, which we know with great confidence.

Question: Can we use the temperatures on other planets to determine what the climate system feedback will be on earth?

The atmospheres of nearby planets validate the general concept of the greenhouse theory, especially in a qualitative sense, but they cannot tell us what the magnitude of the changes on earth will be. Venus, with its massive atmosphere composed essentially of CO_2, has a surface air temperature close to 500^0 warmer than would be expected without a Greenhouse Effect. Mars, with a very thin atmosphere and thus little atmospheric capacity to absorb radiation, has an observed temperature close to the expected. The earth, with intermediate amounts of greenhouse gases in its atmosphere, is about 30^0 C (54^0 F) warmer than it would be otherwise. The differences among the planets are very large, and cannot really be used to estimate sensitivity to relatively small changes in greenhouse gas levels. Furthermore, as noted above, the big uncertainty lies in the magnitude of the climate system response (or feedbacks). The most important feedbacks involve the reaction or processes related to water, and the other planets have no free-standing water.

Are greenhouse gases increasing?

Since the establishment of an atmospheric monitoring system in 1958, we have observed the concentration of CO_2 growing systematically. During the past 28 years, CO_2 values in our atmosphere have increased from 315 parts per million (ppm) to 350 ppm. These values are especially significant since air bubbles trapped within the ice in Greenland and Antarctica have been used to measure what CO_2

concentrations were like over the past several hundred thousand years. During that time, up to just prior to the industrial revolution, CO_2 levels had not exceeded 280 ppm (and thus were well below current values). The rising CO_2 concentrations are believed to be associated with the widespread use of fossil fuels such as gas and oil and by the denuding of the world's tropical and other forests, a process which lowers the earth's ability to use trees as a CO_2 absorbent.

Chlorofluorocarbons (CFCs), better known for their impact on atmospheric ozone levels, are artificially generated gases that also have the capacity to contribute to the Greenhouse Effect, and which are known to be increasing. They have no natural sources and probably did not exist in the atmosphere prior to the last few decades. Recent measurements indicate that other contributing greenhouse gases, such as methane and nitrous oxide, are also increasing; however, since we are not sure of the reason for their increase, we have less confidence in their long-term trends.

Question: Is the temperature record of the past century consistent with the increase of gases which contribute to the Greenhouse Effect?

It is estimated that the average surface air temperature has increased globally by about 0.6^0 C (or 1^0 F) in the past century, but there is some uncertainty as to how accurately the change can be estimated because there were far fewer temperature recording stations 100 years ago. Large portions of the globe were poorly sampled, especially in the Southern Hemisphere. Even today, full global coverage is not available.

The record, such as it is, does not indicate a continuous worldwide

warming. There was apparently a cooling period in the Northern Hemisphere from the 1940s into the early 1970s. This is inconsistent with the concept of greenhouse warming, but it may be due to other climate disturbances such as variations in the solar energy constant, or a change in the amount of volcanic discharge into the atmosphere, or it may simply represent internal variability within the system.

The overall warming for the past century is the right order of magnitude for the expected Greenhouse Effect. However, given the uncertainties about the actual temperature change, the climate feedback factor, the actual amount of CO_2 in the atmosphere in 1880, and the rate at which oceans absorb heat (which slows down the atmospheric warming), we cannot be more precise in determining what the expected warming would have been. Similarly, we cannot use the record to establish what the climate-feedback factor really is.

Despite these qualifications, one aspect of the temperature record clearly stands out: during the past century, the four warmest years, globally, were all during the 1980s; this does not include 1988, which appears as if it will be the warmest year of all. This has occurred despite the eruption of the El Chicon volcano, putting additional dust into the air, and a decrease in the sun's energy output, both of which should have had a cooling effect. While modern temperature records may be contaminated to some extent by heat island effects which create warm areas in cities, the rapid rise of temperature during the 1980s is consistent with computer model projections. This suggests that the anticipated Greenhouse Effect changes may actually be appearing at this time.

Question: Are current computer models adequate to allow us to forecast climate change?

Numerical models (called general circulation models) which simulate the known workings of the earth's climate system are used to calculate its response to increases in trace gases. The four models in current use all estimate that the doubled CO_2 climate will have a global average temperature some 4^0 C (7^0 F) warmer than today. They are thus all calculating similar climate feedback factors. However, even though many climate processes are handled similarly in the different models, their unanimity does not guarantee accuracy. For example, the treatment of cloud cover in all the models represents a major uncertainty. The models also differ to some extent as to the seasonal and latitudinal distributions of the calculated warming. It is thought unlikely that the models could be wrong by more than a factor of two, but this cannot be proven.

In addition, a climate change forecast should indicate when the warming would be expected to be evident, but only one model, the Goddard Institute of Space Studies (GISS) model, has been used to calculate the temperature increase over the next 50 years in response to a gradual change in greenhouse gas concentrations. Its results indicate substantial warming in the next decade. This calculation is affected to some extent by uncertainties in how much heat the oceans will absorb and the true climate feedback factor. Nonetheless, by providing an estimate of how much warming should be observed in the relatively near future, the model does give us a chance to test the accuracy of its projections.

Question: How "dire" is the forecast of coming climate change?

It is estimated that the ice age climate was some 4^0 C colder than today's. At that time (some 18,000 years ago), ice covered the area now occupied by New York City. Considering that the doubled CO_2 climate is estimated to be warmer to the same degree that the ice ages were cooler, large changes in the climate system may well be expected if this comes to pass. The GISS model's forecast for the next 50 years gives changes of 2^0 C (3.6^0 F) by the year 2020, which would make the earth warmer than it is thought to have been at any point in historical time. Estimates for summer temperatures in the doubled CO_2 climate indicate that Washington, DC, which currently experiences 36 days of temperature above 90^0 F would routinely have 87 such days; Dallas would go from 19 days with temperatures above 100^0 F to 78 days.

Sea-level rise due to thermal expansion of the oceans would cause severe problems in many coastal cities, and this effect would be exacerbated if additional glacial melting occurred. Rainfall patterns would likely be substantially altered, posing the threat of large-scale disruptions of agricultural and economic productivity, and water shortages in some areas.

We may start experiencing the effects of a changing climate fairly soon. If we define a "hot" summer as the warmest one-third of the summers during the period 1950-1980, then, if the models are correct, during the 1990s we will experience "hot" summers twice as often, or two-thirds of the time. The summer of 1988 may be an all-too-tangible indication of how dire such changes in summertime climate can be.

Question: Is there any way to prevent these changes from occurring?

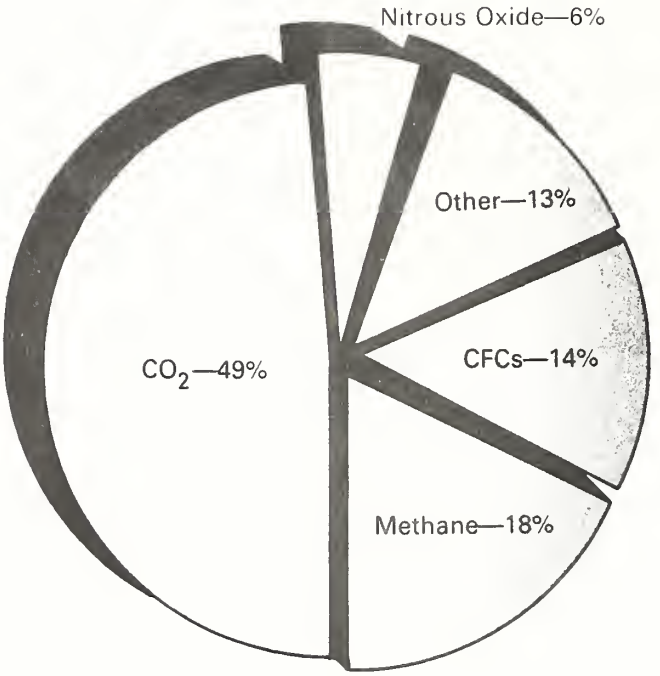
The climate is being altered by the release of greenhouse gases due to fossil fuel consumption and industrial processes, and by deforestation. These factors are inherent in our current civilization. It may be possible to limit specific trace gas increases (such as the CFCs) and slow down rates of increase of CO_2 through increased energy conservation. Our ability to manipulate the climate system deliberately, so as to offset the warming by some other process, is nonexistent. It is likely that the additional greenhouse gases which have been added to the atmosphere during the past 50 years have already built considerable warming into the system, which we have not yet experienced because of the slow warming response of the ocean.

The climate of the next century will very likely be substantially different from that to which we have become accustomed. Uncertainties in our knowledge of the true climate sensitivity prevent us from knowing exactly how different it will be. The consequences of the climate change that is currently being estimated would be enormous. With that in mind, it is worthwhile for us to factor climatic change into decision-making processes related to our future, even though there are many uncertainties that still exist in our understanding of what may actually happen. □

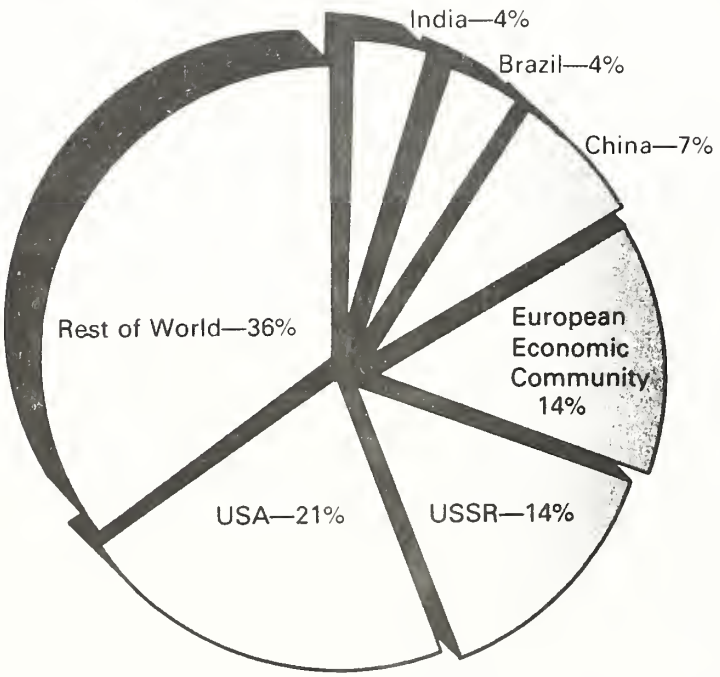
(Dr. Rind is an atmospheric scientist at the Institute for Space Studies, Goddard Space Flight Center, National Aeronautics and Space Administration, and an adjunct associate professor at Columbia University. He is a leading researcher on aspects of the greenhouse theory of atmospheric warming from certain gases.)

EPA Journal (Jan/Feb 1989)

Manmade Contributions to the Greenhouse Effect



Regional Contributions to the Greenhouse Effect

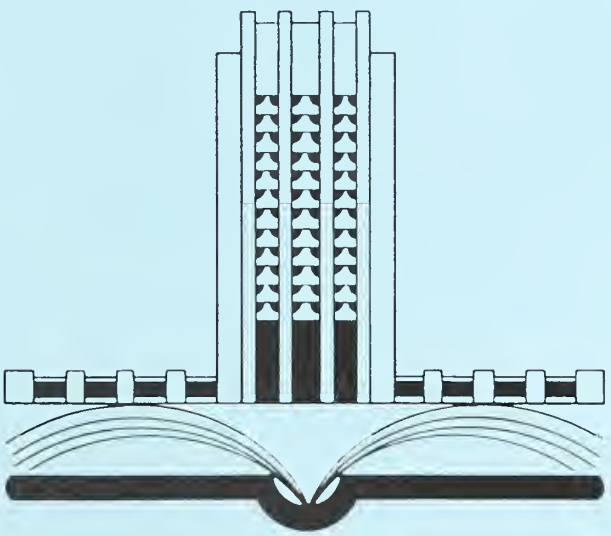


(The top chart represents the estimated increase in the Greenhouse Effect due to manmade emissions of Greenhouse gases in the 1980s. The chart is adapted from work by Dr. James Hansen and his associates at the Goddard Institute for Space Studies. The bottom chart is based on EPA estimates of each region's contribution to manmade emissions of Greenhouse gases.)

Global Warming and the Greenhouse Effect

January 1986 - January 1992

QB 92-36
Quick Bibliography Series



Bibliographies in the Quick Bibliography Series of the National Agricultural Library, are intended primarily for current awareness, and as the title of the series implies, are not in-depth exhaustive bibliographies on any given subject. However, the citations are a substantial resource for recent investigations on a given topic. They also serve the purpose of bringing the literature of agriculture to the interested user who, in many cases, could not access it by any other means. The bibliographies are derived from computerized on-line searches of the AGRICOLA data base. Timeliness of topic and evidence of extensive interest are the selection criteria.

The author/searcher determines the purpose, length, and search strategy of the Quick Bibliography. Information regarding these is available upon request from the author/searcher.

To request a copy of a bibliography in this series, send the title , series number and self-addressed gummed label to:

U.S. Department of Agriculture
National Agriculture Library
Public Services Division, Room 111
Beltsville, Maryland 20705

Global Warming and the Greenhouse Effect

January 1986 - January 1992

Quick Bibliography Series: QB 92-36
Updates QB 90-56

442 citations in English from AGRICOLA

Jayne T. MacLean
Alternative Farming Systems Information Center

Alternative
Farming
Systems

National Agricultural Library Beltsville, Maryland 20705-2351 March 1992

National Agricultural Library Cataloging Record:

MacLean, Jayne T.
Global warming and the greenhouse effect.
(Quick bibliography series ; 92-36)
1. Global warming – Bibliography. 2. Greenhouse effect, Atmospheric – Bibliography. I. Title.
aZ5071.N3 no.92-36

United States Department of Agriculture | National Agricultural Library | Public Services Division | Beltsville, Maryland 20705

Document Delivery Services to Individuals

The National Agricultural Library (NAL) supplies agricultural materials not found elsewhere to other libraries.

Filling requests for materials readily available from other sources diverts NAL's resources and diminishes its ability to serve as a national source for agricultural and agriculturally related materials. Therefore, NAL is viewed as a library of last resort. Submit requests first to local or state library sources prior to sending to NAL. In the United States, possible sources are public libraries, land-grant university or other large research libraries within a state. In other countries submit requests through major university, national, or provincial institutions.

If the needed publications are not available from these sources, submit requests to NAL with a statement indicating their non-availability. Submit one request per page following the instructions for libraries below.

NAL's Document Delivery Service Information for the Library

The following information is provided to assist your librarian in obtaining the required materials.

Loan Service – Materials in NAL's collection are loaned only to other U.S. libraries. Requests for loans are made through local public, academic, or special libraries.

The following materials are not available for loan: serials (except USDA serials); rare, reference, and reserve books; microforms; and proceedings of conferences or symposia. Photocopy or microform of non-circulating publications may be purchased as described below.

Document Delivery Service – Photocopies of articles are available for a fee. Make requests through local public, academic, or special libraries. The library will submit a separate interlibrary loan form for each article or item requested. If the citation is from an NAL database (CAIN/AGRICOLA, *Bibliography of Agriculture,* or the NAL Catalog) and the call number is given, put that call number in the proper block on the request form. Willingness to pay charges must be indicated on the form. Include compliance with copyright law or a statement that the article is for "research purposes only" on the interlibrary loan form or letter. Requests cannot be processed without these statements.

Charges:

- Photocopy, hard copy of microfilm and microfiche – $5.00 for the first 10 pages or fraction copied from a single article or publication. $3.00 for each additional 10 pages or fraction.
- Duplication of NAL-owned microfilm – $10.00 per reel.
- Duplication of NAL-owned microfiche – $ 5.00 for the first fiche and $ .50 for each additional fiche per title.

Billing – Charges include postage and handling, and are subject to change. Invoices are issued quarterly by the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. Establishing a deposit account with NTIS is encouraged. *DO NOT SEND PREPAYMENT.*

Send Requests to:

USDA, National Agricultural Library
Document Delivery Services Branch, 6th Fl.
10301 Baltimore Blvd.
Beltsville, Maryland 20705-2351

Contact the Head, Document Delivery Services Branch in writing or by calling (301) 504-5755 with questions or comments about this policy.

ELECTRONIC MAIL ACCESS FOR INTERLIBRARY LOAN (ILL) REQUESTS

The National Agricultural Library (NAL), Document Delivery Services Branch accepts ILL requests from libraries via several electronic services. All requests must comply with established routing and referral policies and procedures. The transmitting library will pay all fees incurred during the creation of requests and communication with NAL. A sample format for ILL requests is printed below along with a list of the required data/format elements.

ELECTRONIC MAIL - (Sample form below)

SYSTEM	ADDRESS CODE
INTERNET	LENDINGBR@ASRR.ARSUSDA.GOV
EASYLINK	62031265
ONTYME	NAL/LB
TWX/TELEX	Number is 710-828-0506 NAL LEND. This number may only be used for ILL requests.
FTS2000	A12NALLEND
OCLC	NAL's symbol AGL need only be entered once, but it must be the last entry in the Lender string. Requests from USDA and Federal libraries may contain AGL anywhere in the Lender String.

SAMPLE ELECTRONIC MAIL REQUEST

AG University/NAL ILLRQ 231 9/1/91 NEED BY: 10/1/91

Interlibrary Loan Department
Agriculture University
Heartland, IA 56789

Dr. Smith Faculty Ag School

Canadian Journal of Soil Science 1988 v 68(1): 17-27
DeJong, R. Comparison of two soil-water models under semi-arid growing conditions
Ver: AGRICOLA
Remarks: Not available at IU or in region.
NAL CA: 56.8 C162

Auth: C. Johnson CCL Maxcost: $15.00

MORE

TELEFACSIMILE - Telephone number is 301-504-5675. NAL accepts ILL requests via telefacsimile. Requests should be created on standard ILL forms and then faxed to NAL. NAL does not fill requests via Fax at this time.

REQUIRED DATA ELEMENTS/FORMAT

1. Borrower's address must be in block format with at least two blank lines above and below so form may be used in window envelopes.
2. Provide complete citation including verification, etc.
3. Provide authorizing official's name (request will be rejected if not included).
4. Include statement of copyright compliance if applicable.
5. Indicate willingness to pay applicable charges.
6. Include NAL call number if available.

Contact the Document Delivery Services Branch at (301) 504-6503 if additional information is required.

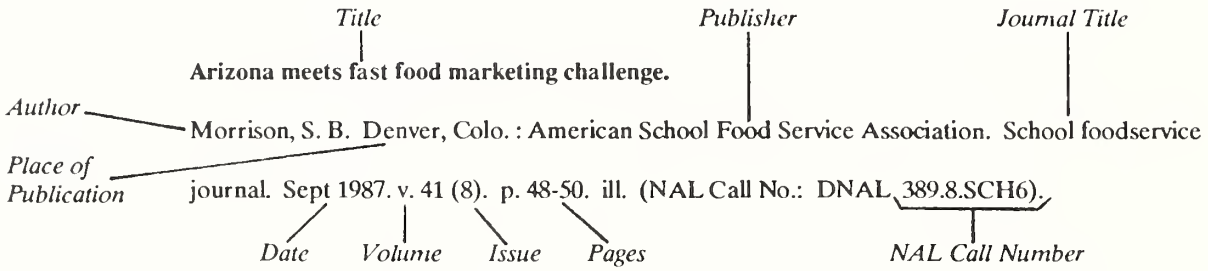
AGRICOLA

Citations in this bibliography were
entered in the AGRICOLA
database between January 1979
and the present.

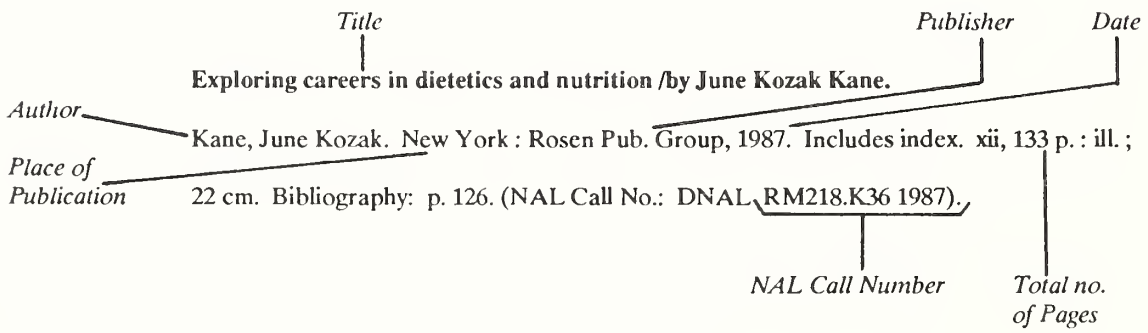
SAMPLE CITATIONS

Citations in this bibliography are from the National Agricultural Library's AGRICOLA database. An explanation of sample journal article, book, and audiovisual citations appears below.

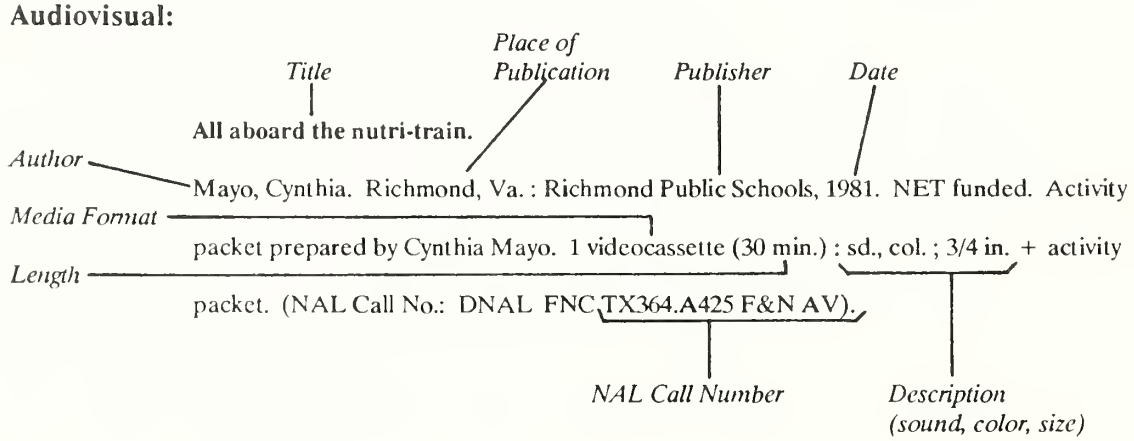
Journal Article:



Book:



Audiovisual:



GLOBAL WARMING AND THE GREENHOUSE EFFECT

SEARCH STRATEGY

```
Line Command
---- -------
   1. S SH=B200 AND (CO2 OR CARBON()DIOXIDE/TI,DE)
   2. SS SH=B200 AND WARMING
   3. S S1 OR S4
   4. SS S5 OR GLOBAL/TI,DE()WARMING/TI,DE
   5. SS S9 OR GREENHOUSE/TI,DE()EFFECT?/TI,DE
   6. SS S2 AND CLIMAT?/TI,DE(N)WARMING/TI,DE
   7. S S17 OR S13
   8. S S2 AND CLIMAT?()CHANGE?/TI,DE
   9. S S18 OR S19
  10.  SS  OZONE  AND  (STRATOSPHER?  OR  HOLE  OR  DEPLETION  OR
      DESTRUCTION)
  11. S S20 OR S26
  12.  SS  (RADIATION  OR  IRRADIA?)  AND  (UV? OR ULTRAVIOLET  OR
      ULTRA()VIOLET)
  13. S S2 AND S35
  14. S S36 OR S27
  15. S S37 NOT PALEO?
  16.  SS  (GREENHOUSE()GAS?  OR  METHANE  OR  NITROUS()OXIDE  OR
      CARBON()DIOXIDE) AND EMISSION?
  17. S S38 OR S50
  18. S S51 AND S2
  19. L52/ENG
  20. S S53 AND UD=8501:9999
  21. SS S54 AND UD=8601:9999
```

GLOBAL WARMING AND THE GREENHOUSE EFFECT

1 NAL Call No: 472 N21
A 1,400-year tree-ring record of summer temperatures in Fennoscandia.
Briffa, K.R.; Bartholin, T.S.; Eckstein, D.; Jones, P.D.; Karlen, W.; Schweingruber, F.H.; Zetterberg, P.
London : Macmillan Magazines Ltd; 1990 Aug02.
Nature v. 346 (6283): p. 434-439; 1990 Aug02. Includes references.

Language: English

Descriptors: Sweden; Pinus sylvestris; Woody plants; Growth rings; Temperatures; Summer; Historical records

Abstract: Tree-ring data have been used to reconstruct the mean summer (April-August) temperature of northern Fennoscandia for each year from AD 500 to the present. Summer temperatures have fluctuated markedly on annual, decadal and century timescales. There is little evidence for the existence of a Medieval Warm Epoch, and the Little Ice Age seems to be confined to the relatively short period between 1570 and 1650. This challenges the popular idea that these events were the major climate excursions of the first millennium, occurring synchronously throughout Europe in all seasons. An analysis of past warming trends suggests that any summer warming induced by greenhouse gases may not be detectable in this region until after 2030.

2 NAL Call No: QH540.N3
Action spectra and their key role in assessing biological consequences of solar UV-B radiation change.
Caldwell, M.M.; Camp, L.B.; Warner, C.W.; Flint, S.D.
Berlin, W. Ger. : Springer-Verlag; 1986.
N.A.T.O. A.S.I (Advanced Study Institute) series. Series G. Ecological sciences v. 8: p. 87-111; 1986. Paper presented at the "Workshop on The Impact of Solar Ultraviolet Radiation upon Terrestial Ecosystems: 1. Agricultural Crops," Sept 27-30, 1983, Windsheim, West Germany. Includes references.

Language: English

Descriptors: Plant damage; Ultraviolet radiation; Ozone; Reduction; Wavelengths; Photosynthesis; Inhibition; Latitude

3 NAL Call No: QC882.A35
Aerosols and climate.
Hobbs, Peter Victor,1936-; McCormick, M. Patrick
International Association of Meteorology and Atmospheric Physics, International Union of Geodesy and Geophysics, General Assembly1987 :University of British Columbia)
Symposium on Aerosols and Climate 1987 : University of British Columbia.
Hampton, Va., USA : A. Deepak Pub.; 1988.
ix, 486 p. : ill. ; 24 cm. (Studies in geophysical optics and remote sensing). Selected papers from the Symposium on Aerosols and Climate organized by the International Association of Meteorology and Atmospheric Physics at the XIX General Assembly of the International Union of Geodesy and Geophysics, held at the University of British Columbia, Vancouver, Canada, 9-22 August 1987. Includes bibliographies and indexes.

Language: English

Descriptors: Aerosols; Congresses; Climatic changes; Congresses; Troposphere; Congresses; Stratosphere; Congresses

4 NAL Call No: 18 J825
After-effect of elevated night temperature and heat-preconditioning on net carbon dioxide exchange and grain development in Sorghum bicolor L.
Ogunlela, V.B.; Eastin, J.D.
Berlin, W. Ger. : Paul Parey; 1985 May.
Zeitschrift fur Acker- und Pflanzenbau; Journal of agronomy and crop science v. 154 (3): p. 182-192; 1985 May. Includes references.

Language: English

Descriptors: Nebraska; Sorghum bicolor; Carbon dioxide; Gas exchange; Cereals; Plant development; Growth stages; Heat; Night temperature; Field experimentation

5 NAL Call No: SB192.C2C2
Afternoon session, April 4, 1989: The greenhouse gases.
Dever, D.
Winnipeg : The Council; 1989.
Proceedings of the annual meeting - Canada Grains Council (20): p. 82-115; 1989. Meeting held April 4-5, 1989, Winnipeg, Manitoba. Discussion p. 183-185.

Language: English

Descriptors: Climatic change; Atmosphere

6 NAL Call No: 1.98 AG84

Agriculture and the greenhouse effect.
Miller, S.; Senft, D.
Washington, D.C. : The Administration; 1988 Mar.
Agricultural research - U.S. Department of Agriculture, Agricultural Research Service v. 36 (3): p. 6-9. ill; 1988 Mar.

Language: English

Descriptors: U.S.A.; Carbon dioxide; Climatic factors; Crop yield; Greenhouse crops; Greenhouse culture; Temperatures

7 **NAL Call No: QC903.A37**
Agriculture, forestry, and global climate change, a reader.
Library of Congress, Congressional Research Service, United States, Congress, Senate, Committee on Agriculture, Nutrition, and Forestry
Washington : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.Ag 8/3:S.prt.101-26.
ix, 618 p. : ill., maps ; 23 cm. (S. prt. ; 101-26). At head of title: 101st Congress, 1st session. Committee print. April 1989. Includes bibliographies.

Language: English

Descriptors: Global temperature changes; Environmental aspects; Greenhouse effect, Atmospheric; Climatic changes; Environmental aspects; Crops and climate; Meteorology, Agricultural; Forest meteorology

8 **NAL Call No: 10 OU8**
Agrometeorology and model building.
Hume, C.J.; Callander, B.A.
Oxon : C.A.B. International; 1990.
Outlook on agriculture v. 19 (1): p. 25-30. maps; 1990. Includes references.

Language: English

Descriptors: Agricultural meteorology; Climatic change; Mathematical models; Statistical methods

9 **NAL Call No: S541.5.A4M57**
Alaskan plants and atmospheric carbon dioxide.
Sveinbjornsson, B.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 149-154; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Carbon dioxide; Climatic change; Photosynthesis; Vegetation; Botanical composition

10 **NAL Call No: 470 SCI2**
Amazon deforestation and climate change.
Shukla, J.; Nobre, C.; Sellers, P.
Washington, D.C. : American Association for the Advancement of Science; 1990 Mar16.
Science v. 247 (4948): p. 1322-1325. maps; 1990 Mar16. Includes references.

Language: English

Descriptors: South America; Deforestation; Climatic change; Temperature; Evapotranspiration; Models

Abstract: A coupled numerical model of the global atmosphere and biosphere has been used to assess the effects of Amazon deforestation on the regional and global climate. When the tropical forests in the model were replaced by degraded grass (pasture), there was a significant increase in surface temperature and a decrease in evapotranspiration and precipitation over Amazonia. In the simulation, the length of the dry season also increased; such an increase could make reestablishment of the tropical forests after massive deforestation particularly difficult.

11 **NAL Call No: QC980.4.H3**
An annotated inventory of climatic indices and data sets.
Hattemer-Frey, Holly A.; Quinlan, Frank T.; Karl, Thomas
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washinton, D.C. : U.S. Dept. of Energy, [1986?]; 1986.
xv, 195 p. : ill. ; 28 cm. November 1986. DOE/NBB-0080. Dist. Category UC-11. TR035. Prepared under contract no. DE-AC05-84OR21400. Includes bibliographical references (p. 187-195).

Language: English

Descriptors: Climate; Indexes; Meteorological observations; Indexes

12 **NAL Call No: SD390.7.G73G74**
An approach for generating climate change hypotheticals given limitations in current climate models.
Gibbs, M.J.; Hoffman, J.S.
Washington, D.C. : Conservation Foundation; 1987.

The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 91-111. maps; 1987.

Language: English

Descriptors: Climatic change; Models; Prediction; World problems; Thermal radiation

13 **NAL Call No: KF26.C697 1989**
Arctic and Antarctic ozone depletion hearing before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred First Congress, first session ... February 23, 1989.
United States. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.C 73/7:S.hrg.101-53.
iii, 160 p. : ill. ; 24 cm. (S. hrg. ; 101-53). Distributed to some depository libraries in microfiche.

Language: English

Descriptors: Ozone layer depletion; Atmospheric ozone; Arctic Regions; Atmospheric ozone; Antarctic Regions; Environmental protection

14 **NAL Call No: QH543.P76**
Are land biota a source or a sink for CO2? (A simulation study for the global carbon cycle, including man's impact on the biosphere).
Goudriaan, J.; Ketner, P.
Lisse : Swets & Zeitlinger; 1984.
Progress in biometeorology v. 3: p. 247-252. ill; 1984. Paper presented at the "Symposium on Interactions between Climate and Biosphere," March 21-23, 1983, Osnabruck, West Germany. Includes references.

Language: English

Descriptors: Carbon cycle; Carbon dioxide; Biota; Simulation models; Ecosystems; Land use; Deforestation; Source sink relations

15 **NAL Call No: 99.8 F768**
Ashes in the Amazon.
Savonen, C.
Bethesda, Md. : Society of American Foresters; 1990 Sep.
Journal of forestry v. 88 (9): p. 20-25. ill; 1990 Sep. Includes references.

Language: English

Descriptors: Brazil; Venezuela; Tropical forests; Deforestation; Burning; Ecosystems; Environmental degradation; Climatic change; Population pressure; Shifting cultivation; Resource conservation

16 **NAL Call No: SB123.3.C57**
Aspects of photosynthetic biochemistry and climatic change.
Woolhouse H.W.
New York : Belhaven Press; 1990.
Climatic change and plant genetic resources / edited by M.T. Jackson, B.V. Ford-Lloyd, M.L. Parry. p. 34-39; 1990. Includes references.

Language: English

Descriptors: Climatic change; Carbon dioxide; Gases; Interactions; Photosynthesis; Plant communities; Plant physiology; Biochemistry

17 **NAL Call No: SD13.C35**
Assessing economic benefits of climate change on Canada's boreal forest.
Kooten, G.C. van; Arthur, L.M.
Ottawa, Ont. : National Research Council of Canada; 1989 Apr.
Canadian journal of forest research; Journal canadien de recherche forestiere v. 19 (4): p. 463-470. maps; 1989 Apr. Includes references.

Language: English

Descriptors: Canada; Boreal forests; Climatic change; Forestry; Economic impact; Productivity; Mathematical models; Carbon dioxide

18 **NAL Call No: SB123.3.C57**
An assessment of the effects of climatic change on agriculture.
Parry, M.L.; Carter, T.R.
New York : Belhaven Press; 1990.
Climatic change and plant genetic resources / edited by M.T. Jackson, B.V. Ford-Lloyd, M.L. Parry. p. 61-84. maps; 1990. Includes references.

Language: English

Descriptors: Finland; Iceland; Japan; Saskatchewan; U.S.S.R.in europe; Climatic change; Air temperature; Cold zones; Temperate climate; Agricultural research; Economic policy; Environmental impact reporting; Yield response functions

19 **NAL Call No: S541.5.A4M57**
Atmospheric and oceanographic measurement

needed for establishment of data base.
Keeling, C.D.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 11-22; 1984 Mar. Includes references.

Language: English

Descriptors: Carbon dioxide; Cycling in ecosystems; Fossil fuels; Deforestation; Climatic factors; Oceanography

20 NAL Call No: QC879.8.A84
Atmospheric carbon dioxide and the greenhouse effect. (Greenhouse effect.)
United States, Dept. of Energy, Office of Basic Energy Sciences
Washington, D.C. : The Dept. ; Springfield, Va. : Available from the National Technical Information Service, U.S. Dept. of Commerce, [1989?]; 1989.
36 p. : ill., maps ; 28 cm. May 1989. DOE/ER-0411. UC-11. Includes bibliographical references (p. 36).

Language: English

Descriptors: Atmospheric carbon dioxide; Greenhouse effect, Atmospheric; Greenhouse effect, Atmospheric; Research

21 NAL Call No: QH301.B52
Atmospheric carbon dioxide from deforestation in Southeast Asia.
Palm, C.A.; Houghton, R.A.; Melillo, J.M.; Skole, D.L.
St. Louis : Association for Tropical Biology; 1986 Sep.
Biotropica v. 18 (3): p. 177-188. ill; 1986 Sep. Includes references.

Language: English

Descriptors: South east asia; Deforestation; Carbon; Carbon dioxide; Tropical forests; Tropics; Land use; Shifting cultivation; Land clearance; Ecosystems; Biomass

22 NAL Call No: QC879.8.S5
An atmospheric carbon dioxide review and consideration of the mean annual temperature trend at Saskatoon, Saskatchewan.
Shewchuk, S. R.
Saskatchewan Research Council
Saskatoon, Saskatchewan : Saskatchewan Research Council; 1984.
v, 26 leaves : ill. ; 28 cm. (SRC technical report ; no. 160). July, 1984. SRC publication no. E-906-26-B-84. Bibliography: leaves 23-24.

Language: English

Descriptors: Atmospheric carbon dioxide, Saskatchewan; Atmospheric temperature, Saskatchewan; Global temperature changes

23 NAL Call No: Q11.J68
Atmospheric response to 1988 drought conditions and future climate implications.
McCorcle, M.D.
Cedar Falls, Iowa : The Academy; 1990 Sep.
The Journal of the Iowa Academy of Science : JIAS v. 97 (3): p. 84-87. maps; 1990 Sep. Includes references.

Language: English

Descriptors: U.S.A.; Atmosphere; Climatic change; Drought; Soil water; Wind speed

24 NAL Call No: 500 AS73
The average surface temperature of the earth: an energy budget approach.
Pease, R.W.
Washington, D.C. : The Association; 1987 Sep.
Annals of the Association of American Geographers v. 77 (3): p. 450-461. ill; 1987 Sep. Includes references.

Language: English

Descriptors: Climate; Energy balance; Temperature; Carbon dioxide; Air pollution; Energy balance; Simulation models

25 NAL Call No: HD1407.C6
Biocarbon: a model of energy use, forestation, and climate change.
Drennen, T.; Chapman, D.
Ithaca, N.Y. : The Station; 1989 Apr.
Cornell agricultural economics staff paper - Department of Agricultural Economics, Cornell University Agricultural Experiment Station (89-9): 37 p.; 1989 Apr. Includes references.

Language: English

Descriptors: Dendroclimatology; Environmental temperature; Carbon dioxide; Climatic change; Mathematical models

26 NAL Call No: 100 SO82S
Bioclimate: things could get worse.
Brookings, S.D. : The Station; 1989 Mar.
South Dakota farm & home research - South

Dakota, Agricultural Experiment Station v. 40 (1): p. 3-6. maps; 1989 Mar.

Language: English

Descriptors: South Dakota; Climatic change; History; Projections; Drought; Wind erosion

27 **NAL Call No: aQK751.U7 1988**
Biological diversity and global change: habit fragmentation and extinction.
Schonewald-Cox, C.; Stohlgren, T.J.
Broomall, PA : Northeastern Forest Experiment Station, [1989?]; 1989 Sep.
Air pollution effects on vegetation, including forest ecosystems : proceedings of the Second US-USSR Symposium / edited by Reginald D. Noble, Juri L. Martin, and Keith F. Jensen. p. 217-224; 1989 Sep. Papers presented at an International Conference, September 13-25, 1988, at Corvallis, Oregon; Raleigh, North Carolina; Gatlinburg, Tennessee. Includes references.

Language: English

Descriptors: U.S.A.; U.S.S.R.; Habitat destruction; Air pollution; Climatic change; Fragmentation

28 **NAL Call No: QH345.B564**
Biomass of the North American boreal forest: a step toward accurate global measures.
Botkin, D.B.; Simpson, L.G.
Dordrecht : Kluwer Academic Publishers; 1990 Mar.
Biogeochemistry v. 9 (2): p. 161-174. maps; 1990 Mar. Includes references.

Language: English

Descriptors: U.S.A.; Boreal forests; Aerial photography; Biomass production; Carbon cycle; Carbon dioxide; Climatic change; Environmental factors; Mapping

29 **NAL Call No: 470 SCI2**
Boreal forests and the global carbon cycle.
Kauppi, P.; Posch, M.
Washington, D.C. : American Association for the Advancement of Science; 1989 Mar24.
Science v. 243 (4898): p. 1535-1536; 1989 Mar24. Includes references.

Language: English

Descriptors: Forest influences; Boreal forests; Carbon cycle; Climatic change

30 **NAL Call No: QC981.4.B72**
The Breathing planet.
Gribbin, John R.
Oxford [Oxfordshire] ; New York, NY, USA : B. Blackwell ; [London] : New Scientist, 1986 (1987 printing); Reprinted 1986.
xv, 336 p. : ill., maps, ports. ; 24 cm. (New scientist guides). Reprints of articles originally published in New scientist. Includes index.

Language: English

Descriptors: Weather; Climatic changes; Atmospheric chemistry; Environmental aspects; Man; Influence on nature

31 **NAL Call No: QC981.8.C5W68 1989**
Cairo compact and panel reports.
Climate Institute (Washington, D.C.),United Nations Environment Programme, Egypt
World Conference on Preparing for Climate Change 1989 : Cairo, Egypt.
Washington, D.C. : Climate Institute, [1989?]; 1989.
34 p. ; 28 cm. Cover title. At head of title: Cairo climate conference December 17-21, 1989, convened by Climate Institute, United Nations Environment Programme, Government of Egypt. "World Conference on Preparing for Climate Change ... Cairo, Egypt, December 17-21, 1989", P. [i].

Language: English

Descriptors: Climatic changes

32 **NAL Call No: QC912.3.S4**
Can we delay a greenhouse warming? the effectiveness and feasibility of options to slow a build-up of carbon dioxide in the atmosphere.
Seidel, Stephen; Keyes, Dale L.
United States, Environmental Protection Agency, Office of Policy and Resources Management, Strategic Studies Staff
Washington, D.C. : Strategic Studies Staff, Office of Policy Analysis, Office of Policy and Resources Management : For sale by the Supt. of Docs., U.S. G.P.O.; 1983.
1 v. (various pagings) : ill., 1 map ; 28 cm. September 1983. S/N 055-000-00235-5. Bibliography: p. [189-193].

Language: English

Descriptors: Greenhouse effect, Atmospheric; Atmospheric carbon dioxide; Environmental aspects; Fossil fuels; Environmental aspects

33 NAL Call No: 517 OT81
Canada's peatlands: their importance for the global carbon cycle and possible effects of "greenhouse" climatic warming.
Gorham, E.
Ottawa : The Society; 1988.
Transactions of the Royal Society of Canada; Memoires de la Societe royale du Canada v. 3: p. 21-23; 1988. Includes references.

Language: English

Descriptors: Canada; Climatic change; Carbon dioxide; Peatlands; Soil resources

34 NAL Call No: QK710.P55
Canopy photosynthesis of crops and native plant communities exposed to long-term elevated CO2.
Drake, B.G.; Leadley, P.W.
Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 853-860; 1991 Oct. Literature review. Includes references.

Language: English

Descriptors: Crops; Spartina patens; Scirpus; Carbon dioxide enrichment; Photosynthesis; Carbon dioxide; Gas exchange; Canopy; Salt marshes; Plant communities; Air temperature; Literature reviews

35 NAL Call No: S600.7.C54C355
Carbon dioxide and climate change impacts on agriculture. (CO2 and climate change.)
Salinger, M. J.
Palmerston North, N.Z. : DSIR ; [Wellington, N.Z.] : New Zealand Meteorological Service ; [Lincoln, N.Z.] : MAF, [1990?]; 1990.
28 p. : ill. ; 30 cm. Cover title. Caption title: CO2 and climate change. Includes bibliographical references (p. 28).

Language: English

Descriptors: Atmospheric carbon dioxide; Crops and climate; Meteorology, Agricultural

36 NAL Call No: QC879.8.C35 1984
Carbon dioxide and climate summaries of research in FY 1983 and FY 1984.
United States, Dept. of Energy
Washington, D.C. : United States Department of Energy; 1984.
v, 131 p. : ill. ; 28 cm. DOE/ER-0202. September 1984. Includes index.

Language: English

Descriptors: United States, Climate; Atmospheric carbon dioxide, Research, United States

37 NAL Call No: QC879.8.C35
Carbon dioxide and climate summaries of research in FY 1987.
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, D.C. : U.S. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division; 1987.
vii, 95 p. : ill. ; 28 cm. DOE/ER-0347. October 1987. Includes index.

Language: English

Descriptors: United States, Climate; Atmospheric carbon dioxide, Research, United States

38 NAL Call No: QC879.8.C35 1988
Carbon dioxide and climate summaries of research in FY 1988.
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, D.C. : U.S. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division; 1988.
xiv, 87 p. : ill. ; 28 cm. (DOE/ER ; 0385). October 1988. Includes index.

Language: English

Descriptors: United States; Climate; Atmospheric carbon dioxide; Research; United States

39 NAL Call No: QH543.I3
Carbon dioxide and global change earth in transition.
Idso, Sherwood B.
Tempe, Ariz, U.S.A. (631 E. Laguna Dr., Tempe 85282) : IBR Press; 1989.
iii, 292 p. : ill. ; 23 cm. Includes bibliographical references (p. 136-235) and indexes.

Language: English

Descriptors: Bioclimatology; Carbon dioxide; Physiological effect; Global warming; Health aspects

40 NAL Call No: T57.6.A1I5 no.88-7
Carbon dioxide emissions in a methane economy.
Ausubel, Jesse
Laxenburg, Austria : International Institute for Applied Systems Analysis, [c1988]; 1988, reprinted 1988.

p. iii, 245-263 : ill. ; 24 cm. (Research reports / International Institute for Applied Systems Analysis ; 88-7). December 1988. Reprinted from Climatic Change, 12 (1988), 245-263. Includes bibliographical references.

Language: English

41 NAL Call No: S541.5.A4M57
Carbon dioxide in context.
Meeker, J.W.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 187-189; 1984 Mar.

Language: English

Descriptors: Carbon dioxide; Climatic change; Fossil fuels; Resource management

42 NAL Call No: S541.5.A4M57
Carbon dioxide in the Arctic atmosphere: air-sea and air-land interaction.
Kelley, J.J.; Gosink, T.A.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 40-48. ill., maps; 1984 Mar. Includes references.

Language: English

Descriptors: Carbon dioxide; Arctic regions; Oceanography; Seasonal variation; Air-water interface; Climatic change; Arctic tundra

43 NAL Call No: QK1.C83
Carbon dioxide levels in the biosphere: effects on plant productivity.
Wittwer, S.H.
Boca Raton, Fla. : CRC Press; 1985.
Critical reviews in plant sciences v. 2 (3): p. 171-198; 1985. Literature review. Includes 207 references.

Language: English

Descriptors: Plant physiology; Environmental factors; Carbon dioxide; Atmosphere; Climatic factors

44 NAL Call No: QC879.8.J37
Carbon dioxide potential emerging global hazard.
Jarratt, Jennifer
Washington. D.C. : JF Coates, Inc., c1983?; 1983. ii, 43 leaves : ill. ; 28 cm. "The Environmental Program of the Edison Electric Institute sponsored this stock-taking study of the carbon dioxide question", P.i. December 28, 1983. Includes bibliographical references (leaves 41-42).

Language: English

Descriptors: Greenhouse effect, Atmospheric; Climatic changes; Atmospheric carbon dioxide; Environmental aspects

45 NAL Call No: S541.5.A4M57
The carbon dioxide problem: a scientific puzzle and political dilemma.
Woodwell, G.M.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 3-7; 1984 Mar. Includes references.

Language: English

Descriptors: Carbon dioxide; Climatic change; Natural resources; Carbon cycle; Resource management

46 NAL Call No: QC879.8.C36
Carbon dioxide research progress report fiscal year 1979.
Dahlman, Roger C.
United States, Department of Energy
Washington, D.C. : U.S. Dept. of Energy ; Springfield, Va. : Available from National Technical Information Service; 1980.
79 p. : ill., maps ; 28 cm. (Carbon Dioxide Effects Research and Assessment Program (Series) ; no. 005.). Apr 1980. DOE/EV-0071. UC-11. Bibliography: p. 77-79.

Language: English

Descriptors: Atmospheric carbon dioxide; Carbon dioxide

47 NAL Call No: QK477.2.A6I5 1986
Carbon-13/carbon-12 variations in bristlecone pine over the past 600 years and their relation to climate and global atmosphereic CO2.
Long, A.; Leavitt, S.W.; Cheng, S.
Washington, DC : U.S. Department of Energy, Office of Energy Research; 1987 Apr.
Proceedings of the International Symposium on Ecological Aspects of Tree-Ring Analysis / compiled by G.C. Jacoby, J.W. Hornbeck. p. 485-493; 1987 Apr. Includes references.

Language: English

Descriptors: California; Pinus longaeva; Carbon dioxide enrichment; Growth; Climatic factors; Growth rings; Altitudinal zonation

48 NAL Call No: QC981.8.G56C4
The Challenge of global warming.
Abrahamson, Dean E.
Washington, D.C. : Island Press; 1989.
xviii, 358 p. : ill. ; 24 cm. Includes index. Bibliography: p. 327-336.

Language: English

Descriptors: Global warming; Climatic changes; Greenhouse effect, Atmospheric

49 NAL Call No: 470 C16C
Changes in forest fire frequency in Kootenay National Park, Canadian Rockies.
Masters, A.M.
Ottawa, Ont. : National Research Council of Canada; 1990 Aug.
Canadian journal of botany; Journal canadien de botanique v. 68 (8): p. 1763-1767. maps; 1990 Aug. Includes references.

Language: English

Descriptors: British Columbia; Forest fires; Frequency; Stand characteristics; Age composition; Spatial distribution; Climatic change; Environmental impact; Road construction; Rain; Climatic change; Fire suppression; Age of trees; National parks; Fire effects; Fire ecology

50 NAL Call No: 450 J8224
Changes in N and S leaf content, stomatal density and specific leaf area of 14 plant species during the last three centuries of CO2 increase.
Penuelas, J.; Matamala, R.
Oxford : Oxford University Press; 1990 Sep.
Journal of experimental botany v. 230 (41): p. 1119-1124; 1990 Sep. Includes references.

Language: English

Descriptors: Spain; Angiosperms; Gymnosperms; Herbaria; Specimens; Leaves; Chemical composition; Carbon; Sulfur; Nitrogen content; Leaf area; Stomata; Enumeration; Carbon dioxide enrichment; Atmosphere; Climatology; History

Abstract: Parallel to the increase in atmospheric CO2 from 278 micromole mol-1 in AD 1750 to the current ambient level of 348 micromole mol-1, there have been overall decreases in leaf nitrogen content and stomatal density from 144% and 121%, respectively, in AD 1750 to 100% today of herbarium specimens of 14 trees, shrubs, and herbs collected over the last 240 years in Catalonia, a Mediterranean climate area. These decreases were steeper during the initial slower increases in CO2 atmospheric levels as compared with the relatively faster CO2 increases in recent years. The declines in leaf N content and stomatal density have also been reported in experimental studies on leaves of plants grown under enriched CO2 environments. Meanwhile, the stomatal index and overall carbon and sulphur leaf contents have not changed significantly. Leaf S content was higher in the 1940s samples coinciding with the burning of increased quantities of sulphur-rich coal. Consequently, the epidermal cell density has decreased parallel to the stomatal density and the C/N ratio of leaves has increased, implying possible important consequences on herbivores, decomposers, and ecosystems. An overall decrease in the specific leaf area (SLA) from 184% in the 18th century to 100% today has also been found, as would be expected under CO2 enrichment, but which might also be an artifact of prolonged storage.

51 NAL Call No: jQC981.8.C5F33 1986
Changes in the wind earth's shifting climate., 1st ed.
Facklam, Margery; Facklam, Howard
San Diego : Harcourt Brace Jovanovich; 1986.
xiii, 128 p. : ill. ; 24 cm. Includes index. Bibliography: p. 121-124.

Language: English

Descriptors: Climatic changes; Juvenile literature

52 NAL Call No: QC912.3.C481
Changing by degrees steps to reduce greenhouse gases. (Steps to reduce greenhouse gases.)
United States, Congress, Office of Technology Assessment
Washington, DC : Congress of the U.S., Office of Technology Assessment : For sale by the Supt. of Docs., U.S. G.P.O.; 1991; Y 3.T 22/2:2 D 36/3.
x, 354 p. : ill., maps ; 26 cm. "February 1991", P. [4] of cover. Includes index. "OTA-O-482", P. [4] of cover. Includes bibliographical references.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global warming; Climatic changes; Environmental policy

53 NAL Call No: QC912.3.C48
Changing by degrees steps to reduce greenhouse gases : summary. (Steps to reduce greenhouse gases.)
United States, Congress, Office of Technology Assessment
Washington, DC : Congress of the U.S., Office of Technology Assessment : For sale by the Supt. of Docs., U.S. G.P.O.; 1991.
viii, 42 p. : ill., maps ; 26 cm. "February 1991", P. [4] of cover. "OTA-O-483", P. [4] of cover. Includes bibliographical references (p. 41-42).

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global warming; Climatic changes; Environmental policy

54 NAL Call No: SD143.S64
A changing climate and its implications for predicting future yields.
Henderson, J.A.
Bethesda, Md. : The Society; 1990.
Proceedings of the ... Society of American Foresters National Convention. p. 343-346; 1990. Paper presented at a meeting on "Forestry on the Frontier," Sept 24-27, 1989, Spokane, Washington. Includes references.

Language: English

Descriptors: Forest management; Climatic change; Yields; Height; Growth

55 NAL Call No: QH543.P76
Changing climate, changing biomass and changing atmospheric CO2.
Grove, A.T.
Lisse : Swets & Zeitlinger; 1984.
Progress in biometeorology v. 3: p. 5-10; 1984. Paper presented at the "Symposium on Interactions between Climate and Biosphere," March 21-23, 1983, Osnabruck, West Germany. Includes references.

Language: English

Descriptors: Atmosphere; Carbon dioxide; Concentration; Climatic factors; Biological production

56 NAL Call No: QC879.8.N35
Changing climate report of the Carbon Dioxide Assessment Committee.
National Research Council (U.S.). Carbon Dioxide Assessment Committee
Washington, D.C. : National Academy Press; 1983.
xxiii, 496 p. : ill., maps ; 28 cm. Includes bibliographies.

Language: English

Descriptors: Atmospheric carbon dioxide, Environmental aspects, United States; Climatic changes, United States

57 NAL Call No: 450 AN7
Changing productivity of the oceans in response to a changing climate.
Fogg, G.E.
London : Academic Press; 1991 Jun.
Annals of botany v. 67 (suppl.1): p. 57-60; 1991 Jun. Literature review. Includes references.

Language: English

Descriptors: Climatic change; Oceanic climate; Biomass production; Phytotoxicity; Carbon dioxide; Nitrogen; Temperature; Pollution; Literature reviews

Abstract: The probable effects on ocean productivity of a possible 2 degrees C rise in average sea-surface temperature accompanied by a 30 cm rise in mean sea-level over the next 30 years are considered. It seems unlikely that there will be any perceptible change in total primary productivity and changes in secondary productivity seem unpredictable. It is thought unlikely that changes in the nitrogen cycle will be sufficient to affect total biomass over this short time-scale. A 2 degrees C change is, however, likely to bring about considerable alterations in the composition of marine communities, and shifting patterns of water movement will bring about changes in the spatial distribution of biomass, communities and productivity. We may expect changes in traditional fishing grounds and marked changes in flora and fauna in British waters, but probably no increase or decrease in general productivity.

58 NAL Call No: QC879.8.C42
Characterization of information requirements for studies of CO2 effects water resources, agriculture, fisheries, forests, and human health.
White, Margaret R.
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, D.C. : U.S. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division; 1986.
xix, 235 p. : ill. ; 28 cm. December 1985. DOE/ER-0236. Includes bibliographies and indexes.

Language: English

Descriptors: Carbon dioxide; Environmental aspects; Atmospheric carbon dioxide; Environmental aspects; Climatic changes

59 NAL Call No: QH540.E55
Chlorofluorocarbons and the Antarctic ozone 'hole'.
Rowland, F.S.
Geneva : Elsevier Sequoia S.A.; 1986.
Environmental conservation v. 13 (3): p. 193-194; 1986. Includes references.

Language: English

Descriptors: Antarctica; Ozone; Organochlorine compounds; Air pollution; Climatic change

60 NAL Call No: NBUQC981.8 C5 C55 1990
Climate and development climate change and variability and the resulting social, economic and technological implications.
Karpe, H.-J; Otten, Dieter; Trinidade, S. C.
Hamburg Congress on Climate and Development 1988 : Hamburg, Germany.
Berlin ; New York : Springer-Verlag; 1990.
xiv, 477 p. : ill., maps ; 24 cm. "A succinct cross-section of the varying perceptions drawn from the analytical presentations by the unique composition of participants at the Hamburg Congress [on Climate and Development]", pref. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Congresses; Economic development; Congresses; Man; Influence of climate; Congresses

61 NAL Call No: QC879.8.C58
Climate and energy the feasibility of controlling CO2 emissions.
Okken, P. A.; Swart, R. J.; Zwerver, S.
Dordrecht ; Boston : Kluwer Academic Publishers; 1989.
vii, 267 p. : ill. ; 25 cm. Includes bibliographical references.

Language: English

Descriptors: Atmospheric carbon dioxide; Greenhouse effect, Atmospheric; Fossil fuels

62 NAL Call No: S600.2.I58 1987
Climate and food security papers persented at the International Symposium on Climate Variability and Food Security in Developing Countries, 5-9 February 1987 New Delhi, India.
American Association for the Advancement of Science, Indian National Science Academy, International Rice Research Institute, Indian Council of Agricultural Research
International Symposium on Climate Variability and Food Security in Developing Countries 1987 : New Delhi, India.
Manila, Philippines : The Institute ; Washington, D.C. : The Association; 1989.
602 p. : ill., maps ; 23 cm. "CGIAR Information Service. Includes bibliographical references.

Language: English

Descriptors: Crops and climate; Climatic changes

63 NAL Call No: 101 AL1A
Climate change.
Ascher, A.
Edmonton : Faculty of Agriculture and Forestry, University of Alberta; 1990.
Agriculture and forestry bulletin v. 13 (4): p. 3-8. ill; 1990.

Language: English

Descriptors: Canada; Climatic change; Effects; Forestry

64 NAL Call No: KF27.A33277 1989b
Climate change and agriculture joint hearing before the Subcommittee on Department Operations, Research, and Foreign Agriculture and the Subcommittee on Forests, Family Farms, and Energy of the Committee on Agriculture, House of Representatives, One Hundred First Congress, first session, April 19, 1989.
United States. Congress. House. Committee on Agriculture. Subcommittee on Department Operations, Research, and Foreign Agriculture; United States, Congress, House, Committee on Agriculture, Subcommittee on Forests, Family Farms, and Energy
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1990; Y 4.Ag 8/1:101-28.
iii, 150 p. : ill. ; 24 cm. Distributed to some depository libraries in microfiche. Serial no. 101-28. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Crops and climate; Meteorology, Agricultural; United States

65 NAL Call No: aSD11.A42 no.187
Climate change and America's forests.
Joyce, Linda A.; Fosberg, Michael A.; Comanor, Joan M.
Rocky Mountain Forest and Range Experiment Station (Fort Collins, Colo.)
Fort Collins, Colo. : U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1990.
12 p. : ill., maps ; 28 cm. (General technical report RM ; 187). February 1990. Includes bibliographical references (p. 9-12).

Language: English

Descriptors: Forests and forestry; United States; Mensuration; Climatic factors; Greenhouse effect, Atomospheric; United States

66 NAL Call No: QK475.T74
Climate change and forests.
Gates, D.M.
Victoria, B.C. : Heron Publishing; 1990 Dec.
Tree physiology v. 7 (1/4): p. 1-5; 1990 Dec. Paper presented at the "Workshop on Dynamics of Ecophysiological Processes in Tree Crowns and Forest Canopies," September, 1991, Rhinelander, Wisconsin. Includes references.

Language: English

Descriptors: Forest ecology; Climatic change; Temperature; Air pollution; Carbon dioxide

Abstract: Factors governing long-term change in global temperature are reviewed. The magnitude and rate of change in global temperature resulting from current increases in the concentration of atmospheric greenhouse gases are considered in relation to their impact on forests. Movement in forest zone boundaries at a rate of 2.5 km year-1 are possible, which is nearly ten time the rate forests have been known to move by natural reproduction. Climate models indicate that increased global temperature will affect rainfall distribution, lead to more frequent and more severe storms and increase climatic variability. Consequences for the world's forests include increased frequencies of fire and blow-down, and widespread decline. Increased atmospheric CO2 concentrations may increase forest growth where the effect is not offset by reduced precipitation, but the overall effect of anticipated changes in global climate is likely to be widespread loss of forests.

67 NAL Call No: 450 AN7
Climate change and productivity of natural grasslands.
Hall, D.O.; Scurlock, J.M.O.
London : Academic Press; 1991 Jun.
Annals of botany v. 67 (suppl.1): p. 49-55; 1991 Jun.
Literature review. Includes references.

Language: English

Descriptors: Climatic change; Tropical grasslands; Biomass production; Plant communities; Plant ecology; Ecosystems; Burning; Carbon dioxide; Nitrogen; Environmental factors; Temperature; Water stress; Nutrient requirements; Literature reviews

Abstract: Natural grasslands, especially in the tropics, urgently need more detailed study in order to determine the response of this undervalued major ecosystem type to possible climate changes. Feedback effects through environmental variables such as temperature, water and nutrient stress may be at least as significant as the increase in atmospheric CO2 concentration. but there is scarcely enough data at present to develop and validate modelling. Annual burning of large areas of tropical grasslands plays a significant role in the global carbon cycle. Net loss of soil carbon and nitrogen may result, depending upon the frequency of fire, overgrazing and drought. The UNEP Project on productivity and photosynthesis in tropical grasslands attempts to correct the gap in baseline data, and has found these ecosystems to be far more productive than previously appreciated. Based on data from three terrestrial grassland sites, the gross flux of carbon from burning of tropical grasslands falls in the range 2-4 4-2 Gt per annum, a significant amount compared with the net fluxes of 1-8 Gt estimated from deforestation and 9-3 Gt from fossil combustion. Data from this project is also being applied to modelling work in collaboration with SCOPE. In order to study climate change effects on carbon cycling in grasslands.

68 NAL Call No: Q11.J68
Climate change and the potential impact on the soil resource.
Hatfield, J.L.
Cedar Falls, Iowa : The Academy; 1990 Sep.
The Journal of the Iowa Academy of Science : JIAS v. 97 (3): p. 82-83; 1990 Sep. Includes references.

Language: English

Descriptors: Air temperature; Climatic change; En-

vironmental impact reporting; Soil management; Soil resources; Soil temperature; Soil water

69 NAL Call No: QC981.8.C5C5
Climate change and U.S. water resources. (Climate change and US water resources.)
Waggoner, Paul E.
American Association for the Advancement of Science, Panel on Climatic Variability, Climate Change, and the Planning and Management of U.S. Water Resources
New York : Wiley; 1990.
xiii, 496 p. : ill. ; 25 cm. (Wiley series in climate and the biosphere). A Wiley-Interscience publication. Report of the American Association for the Advancement of Science Panel on Climatic Variability, Climate Change, and the Planning and Management of U.S. Water Resources. Includes bibliographical references and index.

Language: English

Descriptors: Climatic changes; United States; Water-supply; United States

70 NAL Call No: SD13.C35
Climate change and wildfire in Canada.
Flannigan, M.D.; Van Wagner, C.E.
Ottawa, Ont. : National Research Council of Canada; 1991 Jan.
Canadian journal of forest research; Journal canadien de recherche forestiere v. 21 (1): p. 66-72. maps; 1991 Jan. Includes references.

Language: English

Descriptors: Canada; Wildfires; Climatic change; Carbon dioxide; Temperature; Models

71 NAL Call No: S600.7.C54P37
Climate change and world agriculture.
Parry, M. L.
London : Earthscan Publications Limited in association with The International Institute for Applied Systems Analysis [and] United Nations Environment Programme; 1990.
xv, 157 p. : ill., maps ; 23 cm. Includes bibliographical references (p. [135]-149) and index.

Language: English

Descriptors: Agriculture; Climatic changes

72 NAL Call No: S600.7.C54M3
Climate change and world food production.
McQuigg, James D.
Gainesville, Fla? : University of Florida?, 1975?; 1975.
13, [17] leaves : ill. ; 28 cm. Cover title. An address to the University of Florida Frontiers of Science Series, Gainesville, Florida, 23 April 1975. Bibliography: leaf [14].

Language: English

Descriptors: Crops and climate; Agricultural productivity; Food supply

73 NAL Call No: aHD1751.A42
Climate change could cause shifts in production.
Reilly, J.; Tobey, J.
Rockville, Md. : The Service; 1991 May.
Agricultural outlook AO - U.S. Department of Agriculture, Economic Research Service (174): p. 30-34; 1991 May.

Language: English

Descriptors: Climatic change; Economic impact; Yields; Agricultural production; Carbon dioxide

74 NAL Call No: NBUQC981.8 G56 C54 1991
Climate change evaluating the socio-economic impacts.
Organisation for Economic Co-operation and Development
Paris : Organisation for Economic Co-operation and Development; 1991.
109 p. : ill. ; 23 cm. Includes bibliographical references.

Language: English

Descriptors: Global warming

75 NAL Call No: QC981.8.C5I57
Climate change the IPCC scientific a ssessment.
Houghton, John Theodore; Jenkins, G. J.; Ephraums, J. J.
Intergovernmental Panel on Climate Change; Intergovernmental Panel on Climate Change, Working Group 1
Cambridge ; New York : Cambridge University Press; 1990.
xxxix, 364 p. : ill. (some col.), maps ; 31 cm. "Report prepared for IPCC by Working Group 1", 7th prelim. p. Published for the Intergovernmental Panel on Climate Change. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Greenhouse gases; Greenhouse effect, Atmospheric

76 NAL Call No: 281.8 C16
Climate change, factors and forecasts.
Wilson, W.R.
Ottawa : Canadian Agricultural Economics and Farm Management Society; 1990 Dec.
Canadian journal of agricultural economics; Revue Canadienne d'economie rurale v. 38 (4,pt.1): p. 667-683; 1990 Dec. Paper presented at a Workshop, July 23-25, 1990, Penticton, British Columbia. Includes references.

Language: English

Descriptors: Climatic change; Air pollution; Trends; Gases

77 NAL Call No: NBUQC981.8.C5C541 1987
Climate crisis the societal impacts associated with the 1982-83 worldwide climate anomalies. (Impact, climate crisis Lugano report The Societal impacts associated with the 1982-83 worldwide climate anomalies.)
Glantz, Michael H.; Katz, Richard W.; Krenz, Maria
National Center for Atmospheric Research (U.S.), Environmental and Societal Impacts Group, United Nations Environment Programme
Boulder, Colo. : Environmental and Societal Impacts Group, National Center for Atmospheric Research ; New York, N.Y. : Obstainable from United Nations Publications; 1987.
105 p. : col. ill., col. maps ; 28 cm. Cover title: Impact, climate crisis. Running title: Lugano report. Report based on the Workshop on the Economic and Societal ImpactsAssociated with the 1982-83 Worldwide Climate Anomalies, 11-13 November 1985, Lugano, Switzerland. Includes bibliographical references.

Language: English

Descriptors: Climatic changes, Social aspects; Climatology, Social aspects; Climatic extremes, Social aspects; Environmental impact analysis, Social aspects

78 NAL Call No: QC981.8.C5C48
The Climate of Europe past, present and future : natural and man-induced climate changes : a European perspective.
Flohn, Hermann; Fantechi, Roberto
Commission of the European Communities
Dordrecht ; Boston : Reidel; 1984.
x, 356 p. : ill., maps ; 25 cm. (Atmospheric sciences library). At head of title: Commission of the European Communities. Includes bibliographical references (p. 315-350) and index.

Language: English

Descriptors: Climatic changes; Europe

79 NAL Call No: QC981.8.C5K65
Climate shocks natural and anthropogenic.
Kondrat
New York : Wiley; 1988.
xviii, 296 p. : ill. ; 24 cm. (Wiley series in climate and the biosphere). A Wiley-Interscience publication. Includes bibliographical references and index.

Language: English; Russian

Descriptors: Climatic changes; Greenhouse effect, Atmospheric; Volcanoes; Nuclear explosions

80 NAL Call No: KF27.C697 1989
Climate surprises hearing before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred First Congress, first session, on possible climate surprises, predicting greenhouse warning [i.e. warming], May 8, 1989.
United States. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.C 73/7:S.hrg.101-128.
iii, 152 p. : ill. ; 24 cm. (S. hrg. ; 101-128). Distributed to some depository libraries in microfiche. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Greenhouse effect, Atmospheric; Global warming; Environmental protection; United States

81 NAL Call No: GB395.A73
Climate, tree-ring, and glacial fluctuations in the Rio Frias Valley, Rio Negro, Argentina.
Villalba, R.; Leiva, J.C.; Rubulls, S.; Suarez, J.; Lenzano, L.
Boulder, Colo. : Institute of Arctic and Alpine Research, University of Colorado; 1990 Aug.
Arctic and alpine research v. 22 (3): p. 215-232. ill., maps; 1990 Aug. Includes references.

Language: English

Descriptors: Argentina; Climatic change; Moraine soils; Glacial soils; Date; Dendrochronology;

Growth rings; Width; Historical records

82 NAL Call No: Q11.J68
Climate trends in Iowa.
Carlson, R.E.
Cedar Falls, Iowa : The Academy; 1990 Sep.
The Journal of the Iowa Academy of Science : JIAS v. 97 (3): p. 77-81; 1990 Sep. Includes references.

Language: English

Descriptors: Iowa; Agroclimatology; Air temperature; Climatic change; Heat stress; Trends; Weather data

83 NAL Call No: aSD433.A53 no.65
Climate variability and ecosystem response proceedings of a long-term ecological research workshop, Niwot Ridge/Green Lakes Valley LTER site, Mountain Research Station, University of Colorado, Boulder, Colorado, August 21-23, 1988.
Greenland, David,1940-; Swift, Lloyd Wesley,
Southeastern Forest Experiment Station (Asheville, N.C.)
Asheville, N.C. : U.S. Dept. of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1990; A 13.88:SE-65.
iv, 90 p. : ill., maps ; 28 cm. (General technical report SE ; 65). "October 1990", P. [2] of cover. Includes bibliographical references.

Language: English

Descriptors: Bioclimatology; Ecology; Climatic changes

84 NAL Call No: GB395.A73
Climate variations in northern North America (6000 BP to present) reconstructed from pollen and tree-ring data.
Diaz, H.F.; Andrews, J.T.; Short, S.K.
Boulder, Colo. : Institute of Arctic and Alpine Research, University of Colorado; 1989 Feb.
Arctic and alpine research v. 21 (1): p. 45-59. maps; 1989 Feb. Includes references.

Language: English

Descriptors: Alaska; Canada; Greenland; Pollen analysis; Growth rings; Climatic change; Temperatures; Precipitation; Summer

85 NAL Call No: S600.7.G56C57 1989
Climate warming and Canada's comparative position in agriculture a summary of Land Evaluation Group report, Implications of climatic warming for Canada's comparative position in agricultural production and trade (publication no. LEG-27). (Rechauffement climatique et position relative du Canada en agriculture.)
Smit, Barry
University of Guelph, Land Evaluation Group, Canada, Atmospheric Environment Service
Ottawa : Environment Canada; 1989.
9, 10 p. ; 28 cm. (Climate change digest, CCD 89-01). Title on added t.p.: Rechauffement climatique et position relative du Canada en agriculture. English and French.

Language: English; French

Descriptors: Global warming; Crops and climate; Crops and climate

86 NAL Call No: QC994.8.C6 no.44
The Climates of the long-term ecological research sites.
Greenland, David,
National Science Foundation (U.S.), Division of Biotic Systems and Resources, University of Colorado, Boulder, Institute of Arctic and Alpine Research
Boulder, Colo. : Institute of Arctic and Alpine Research, University of Colorado; 1987.
81 p. : ill. ; 28 cm. (Occasional paper / University of Colorado Institute of Arctic and Alpine Research, 44). Funded by the National Science Foundation, Division of Biotic Systems and Resources. Bibliography: p. 74.

Language: English

Descriptors: Bioclimatology, United States; Ecology, United States; Climatic changes, United States

87 NAL Call No: QC981.8.C5P57
Climatic catastrophes the international implications of the greenhouse effect and nuclear winter.
Pittock, A. Barrie,
Australian National University, Peace Research Centre
Canberra : Australian National University, Research School of Pacific Studies; 1987.
27 p. ; 30 cm. (Working paper (Australian National University. Peace Research Centre) ; no. 20.). July 1987. This paper is an edited and slightly updated version of one to be published in Natural and Man-Made Hazards ed. M.I. El-Sabh and T.S. Murty (Reidel Pub. Co., Dordrecht, 1987). Bibliography: p. 24-27.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Climate changes; Nuclear winter

88 NAL Call No: SD13.C35
Climatic change: a review of causes.
Harrington, J.B.
Ottawa, Ont. : National Research Council of Canada; 1987 Nov.
Canadian journal of forest research; Journal canadien de recherche forestiere v. 17 (11): p. 1313-1339. ill., maps, , plates; 1987 Nov. Literature review. Includes references.

Language: English

Descriptors: North America; Forests; Geographical distribution; Climatic change; Prediction; Environmental temperature; Environmental factors; Geological processes; Carbon dioxide; Human activity

89 NAL Call No: 58.9 IN7
Climatic change and field drainage.
Armstrong, A.C.; Castle, D.A.
Silsoe : Institution of Agricultural Engineers; 1989.
The Agricultural engineer v. 44 (4): p. 126-127. ill; 1989. Includes references.

Language: English

Descriptors: Uk; Climatic change; Drainage; Soil water; Water management; Flood control

90 NAL Call No: 470 SC12
Climatic change and forests.
Binkley, C.S.
Washington, D.C. : American Association for the Advancement of Science; 1989 Feb24.
Science v. 243 (4894): p. 991; 1989 Feb24. Includes references.

Language: English

Descriptors: Finland; Forests; Climatic change; Carbon dioxide; Growth rate

91 NAL Call No: QC980.C55
Climatic change and grain corn yields in the North American Great Plains.
Liverman, D.M.; Terjung, W.H.; Hayes, J.T.; Mearns, L.O.
Dordrecht : D. Reidel Pub. Co; 1986 Dec.
Climatic change v. 9 (3): p. 327-347; 1986 Dec. Includes references.

Language: English

Descriptors: U.S.A.; Zea mays; Crop yield; Mathematical models; Irrigation requirements; Climatic change; Water use; Efficiency; Climatic factors; Environmental factors; Evapotranspiration; Carbon dioxide; Plains

92 NAL Call No: QL750.O3
Climatic change and its ecological implications at a subantarctic island.
Smith, V.R.; Steenkamp, M.
Berlin, W. Ger. : Springer International; 1990.
Oecologia v. 85 (1): p. 14-24. ill; 1990. Includes references.

Language: English

Descriptors: Antarctica; Plant ecology; Mice; Climatic change; Cycling; Islands

93 NAL Call No: 10 OU8
Climatic change and its implications for agriculture.
Parry, M.L.; Porter, J.H.; Carter, T.R.
Oxon : C.A.B. International; 1990.
Outlook on agriculture v. 19 (1): p. 9-15. maps; 1990. Includes references.

Language: English

Descriptors: Agricultural production; Climatic change; Air pollution; Air temperature; Carbon dioxide; Crop yield; Growth period; Methane; Nitrous oxide; Weather

94 NAL Call No: SB123.3.C57
Climatic change and plant genetic resources.
Jackson, M. T.1948-; Ford-Lloyd, Brian; Parry, M. L.
London ; New York : Belhaven Press; 1990.
xii, 190 p. : ill. ; 24 cm.

Language: English

Descriptors: Crops; Germplasm resources; Crops and climate; Climatic changes; Germplasm resources, Plant; Vegetation and climate

95 NAL Call No: TC423.W33
Climatic change and streamflow in the Southwest.
Osborn, H.B.; Lane, L.J.
New York : American Society of Civil Engineers; 1984.
Water today and tomorrow : proc. of Specialty Conf. sponsored by Irrigation and Drainage Div. of Am. Soc. Civil Engineers, Flatstaff, Az., July 24-26, 1984 / John A. Replogle and Kenneth G.

Renard, Editors. p. 362-371. maps; 1984. Includes references.

Language: English

Descriptors: Weather patterns; Stream flow; Rain; Flood control

96 **NAL Call No: GB611.P7**
Climatic change, hydrology, and water management in arid lands.
Dracup, J.A.
Totowa, N.J. : Rowman & Littlefield; 1987.
Progress in desert research / edited by Louis Berkofsky and Morton G. Wurtele. p. 217-225; 1987. Includes references.

Language: English

Descriptors: Arid lands; Climatic change; Hydrological factors; Water resource management; Planning

97 **NAL Call No: 281.8 C16**
Climatic change impacts on forestry: economic issues.
Van Kooten,
Ottawa : Canadian Agricultural Economics and Farm Management Society; 1990 Dec.
Canadian journal of agricultural economics; Revue Canadienne d'economie rurale v. 38 (4,pt.1): p. 701-710; 1990 Dec. Paper presented at a Workshop, July 23-25, 1990, Penticton, British Columbia. Includes references.

Language: English

Descriptors: Canada; Timbers; Forests; Productivity; Climatic change; Cost benefit analysis; Welfare economics; Economic impact

98 **NAL Call No: QE597.W4**
Climatic change impacts on wind erosion in Saskatchewan, Canada.
Wheaton, E. E.
Saskatchewan Research Council
Saskatoon, Saskatchewan : Saskatchewan Research Council; 1984.
iv, 27 leaves : maps ; 28 cm. (SRC technical report ; no. 153). June, 1984. SRC publication no. E-906-16-B-84. Presented to: Task Force Meeting on Climate Impacts in High-Latitude Areas, April 2 to 6, 1984, Laxenburg, Austria ; At the request of the International Institute for Applied Systems Analysis. Bibliography: leaves 25-27.

Language: English

Descriptors: Soil erosion, Saskatchewan; Wind erosion, Saskatchewan

99 **NAL Call No: 517 OT81**
Climatic change: implications for the prairies.
Stewart, R.B.
Ottawa : Royal Society of Canada; 1986.
Transactions of the Royal Society of Canada; Memoires de la Societe royale du Canada v. 1 (ser.5): p. 67-96. maps; 1986. Paper presented at the symposium "The Prairies and Canada", University of Manitoba, June 2-4, 1986. Literature review. Includes references.

Language: English

Descriptors: Saskatchewan; Canada; U.S.A.; Triticum aestivum; Spring wheat; Prairies; Climatic change; Drought; Yield forecasting; Models

100 **NAL Call No: GB451.2.B66**
Climatic change, rising sea level and the British coast.
Boorman, L. A.; Goss-Custard, J. D.; McGrorty, S.
Institute of Terrestrial Ecology
London : H.M.S.O.; 1989.
24 p. : col. ill., map ; 30 cm. (ITE research publication ; no. 1). At head of title: Natural Environment Research Council, Institute of Terrestrial Ecology. Includes bibliographical references (p. 24).

Language: English

Descriptors: Coasts; Sea level

101 **NAL Call No: 4 AM34P**
Climatic change, weather variability, and corn production.
Thompson, L.M.
Madison, Wis. : American Society of Agronomy; 1986 Jul.
Agronomy journal v. 78 (4): p. 649-653; 1986 Jul. Includes 25 references.

Language: English

Descriptors: North central states of U.S.A.; Zea mays; Climatic factors; Weather; Rain; Nitrogen fertilizers; Temperature; Technology; Trends; Carbon dioxide; Genetic factors; Models; Crop production

102 **NAL Call No: QH1.J62**
Climatic response surfaces from pollen data for some eastern North American taxa.
Bartlein, P.J.; Prentice, I.C.; Webb, T. III

Oxford : Blackwell Scientific Publications; 1986 Jan.
Journal of biogeography v. 13 (1): p. 35-57; 1986 Jan. Includes references.

Language: English

Descriptors: North America; Climatic change; Environmental factors; Plant ecology; Pollen analysis; Precipitation· Temperature

103 NAL Call No: S600.43.M37I5 1990
Climatic risk in crop production models and management for the semiarid tropics and subtropics : proceedings of the International Symposium on Climatic Risk in Crop Production : models and management for the semiarid tropics and subtropics, held in Brisbane, Australia, 2-6 July, 1990.
Muchow, Russell C.; Bellamy, J. A.
International Symposium on Climatic Risk in Crop Production 1990 : Brisbane, Qld.
Wallingford, UK ; [Tucson, AZ, USA] : CAB International; 1991.
x, 548 p. : ill., maps ; 24 cm. Includes bibliographical references and index.

Language: English

Descriptors: Climatic changes; Crops and climate; Arid regions agriculture

104 NAL Call No: 500 AS73
Climatic variability and tree response within the forest-alpine tundra ecotone.
Hansen-Bristow, K.J.; Ives, J.D.; Wilson, J.P.
Washington, D.C. : The Association; 1988 Sep.
Annals of the Association of American Geographers v. 78 (3): p. 505-519. ill; 1988 Sep. Includes references.

Language: English

Descriptors: Colorado; Air temperature; Climatic change; Ecotones; Forest ecology; Forest trees; Growth rings; Treelines and timberlines; Tundra

105 NAL Call No: 292.9 AM34
Climatic variation and surface water resources in the Great Basin Region.
Flaschka, I.; Stockton, C.W.; Boggess, W.R.
Minneapolis, Minn. : American Water Resources Association; 1987 Feb.
Water resources bulletin v. 23 (1): p. 47-57. maps; 1987 Feb. Includes references.

Language: English

Descriptors: Great basin and pacific slope; Surface water; Water resources; Climatic change; Runoff water; Air pollution; Carbon dioxide; Water balance; Projections; Models

106 NAL Call No: QC980.C55
Climatic variation and trends in the boreal forest region of western Canada.
Singh, T.; Powell, J.M.
Dordrecht : D. Reidel Pub. Co; 1986 Jun.
Climatic change v. 8 (3): p. 267-278. maps; 1986 Jun. Includes references.

Language: English

Descriptors: Canada; Boreal forests; Climatic change; Trends; Temperature; Precipitation; Historical records; Plant ecology; Forests

107 NAL Call No: 410 EC7
Climatically induced change in fire frequency in the southern Canadian Rockies.
Johnson, E.A.; Larsen, C.P.S.
Tempe, Ariz. : The Society; 1991 Feb.
Ecology : a publication of the Ecological Society of America v. 72 (1): p. 194-201. maps; 1991 Feb. Includes references.

Language: English

Descriptors: Alberta; Picea engelmannii; Pinus contorta; Forest fires; Climatic change; Frequency; History; Mountain areas; Watersheds

108 NAL Call No: aQK751.U7 1988
CO2-induced climate change and forest resources.
Graham, R.L.; Turner, M.G.; Dale, V.H.
Broomall, PA : Northeastern Forest Experiment Station, [1989?]; 1989 Sep.
Air pollution effects on vegetation, including forest ecosystems : proceedings of the Second US-USSR Symposium / edited by Reginald D. Noble, Juri L. Martin, and Keith F. Jensen. p. 233-241; 1989 Sep. Papers presented at an International Conference, September 13-25, 1988, at Corvallis, Oregon; Raleigh, North Carolina; Gatlinburg, Tennessee. Includes references.

Language: English

Descriptors: Forests; Carbon dioxide; Climatic change

109 NAL Call No: QC981.8.C5S358
The coevolution of climate and life.
Schneider, Stephen Henry; Londer, Randi
San Francisco : Sierra Club Books; 1984.
xii, 563 p. : ill. ; 24 cm. Includes index. Bibliogra-

phy: p. 487-548.

Language: English

Descriptors: Climatic changes; Life (Biology)

110 NAL Call No: 100 N81 (1) no.479
College of Agriculture and Life Sciences, Global Climate Change Symposium, April 9, 1990, McKimmon Center proceedings.
Bruck, Robert I.
Raleigh, N.C. : North Carolina Agricultural Research Service, N.C. State University : order from: Dept. of Agricultural Communications, NCSU; 1990.
89 p. : ill. ; 28 cm. (Bulletin (North Carolina Agricultural Research Service) ; 479.). April 1990. Includes bibliographical references.

Language: English

111 NAL Call No: TJ810.A1S6
A comparison of ultraviolet radiation measured at an arctic and an alpine site.
Ambach, W.; Blumthaler, M.; Wendler, G.
Elmsford, N.Y. : Pergamon Press; 1991.
Solar energy v. 47 (2): p. 121-126; 1991. Includes references.

Language: English

Descriptors: Switzerland; Alaska; Ultraviolet radiation; Measurement; Solar energy; Meteorological observations; High altitude; Arctic regions; Mountain areas; Instrumentation; Models; Snow cover; Reflectance

112 NAL Call No: QC912.3.C65
A Compendium of options for government policy to encourage private sector responses to potential climate change report to the Congress of the United States : executive summary.
United States, Dept. of Energy, Assistant Secretary for Environment, Safety, and Health
Washington, DC : U.S. Dept. of Energy, Office of Environmental Analysis, Assistant Secretary for Environment, Safety and Health ; Springfield, Va. : Available from the National Technical Information Service, U.S. Dept. of Commerce; 1989.
xxiii, 94 p. ; 28 cm. October 1989. DOE/EH-0102.

Language: English

Descriptors: United States; Industries; Environmental aspects; Greenhouse effect, Atmospheric; Climatic changes

113 NAL Call No: TD885.5.C3C8
A Comprehensive plan for carbon dioxide effects research and assessment.
United States, Dept. of Energy, Carbon Dioxide and Climate Division
Washington, D.C. The Office ; Springfield, Va. : Available from National Technical Information Service, 1980-; 1980-9999.
v. : ill., maps ; 28 cm. (Carbon Dioxide Effects Research and Assessment Program (Series) ; 008, 013, etc.). "DOE/EV-0094"-pt. 1 ; "DOE/EV/10019"-v.II. UC-11. Includes bibliographies.

Language: English

Descriptors: Atmospheric carbon dioxide; Climatic changes

114 NAL Call No: 450 P5623
Computer calculation of solar ultraviolet radiation at ground level.
Bjorn, L.O.; Murphy, T.M.
Paris : Gauthier-Villars; 1985 Sep.
Physiologie vegetale v. 23 (5): p. 555-561; 1985 Sep. Includes references.

Language: English

Descriptors: Solar radiation; Ultraviolet radiation; Computer software; Computer analysis

115 NAL Call No: SD390.7.G73G74
A conceptual framework for assessing impacts of carbon dioxide change on forest industries.
Rose, D.W.; Ek, A.R.; Belli, K.L.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 259-275. maps; 1987. Includes refe ences.

Language: English

Descriptors: U.S.A.; Forest management; Forest products industries; Decision making; Climatic change; Carbon dioxide; Thermal radiation; Supply balance; Forest trees; Geographical distribution

116 NAL Call No: QC981.8.C5C67 1989
Conference on Climate and Water, Helsinki, Finland, 11-15 September 1989.
World Meteorological Organization, Finland, Ymparistoministerio, Unesco

Conference on Climate and Water 1989 : Helsinki, Finland.
Helsinki : Government Printing Centre; 1989.
2 v. : ill. ; 25 cm. (Suomen Akatemian julkaisuja ; 1989/9). Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Hydrology; Water resources development

117 NAL Call No: QC981.8.C5N35
Confronting climate change strategies for energy research and development.
National Research Council (U.S.). Committee on Alternative Energy Research and Development Strategies
Washington, D.C. : National Academy Press; 1990.
xv, 127 p. : ill. ; 26 cm. DOE/eh/89927P-H1. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Greenhouse gases; Greenhouse effect, Atmospheric; Power resources

118 NAL Call No: S541.5.A4M57
Continental shelf carbon export: an organic sink of the global carbon dioxide cycle.
McRoy, C.P.; Walsh, J.J.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 49-56. maps; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Siberia; Carbon dioxide; Cyclic fluctuations; Biota; Marine areas; Carbon cycle; Oceanography

119 NAL Call No: QC912.3.C6
Cooling the greenhouse vital first steps to combat global warming : recommendations for U.S. policies and actions from the Natural Resources Defense Council.
Natural Resources Defense Council
Washington, D.C. : Natural Resources Defense Council; 1989.
vi, 72 p. ; 22 cm. "Third printing (minor revisions) may 1989", T.p. verso.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global warming

120 NAL Call No: QC981.8.C5N67 1988
Coping with climate change proceedings of the Second North American Conference on Preparing for Climate Change, a cooperative approach.
Climate Institute (Washington, D.C.)
North American Conference on Preparing for Climate Change 2nd : 1988 : Climate Institute.
Washington, D.C. : Climate Institute; 1989.
xi, 696 p., [4] leaves of plates : ill. ; 28 cm. Held in Washington, D.C., Dec. 6-8, 1988. June 1989. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Congresses; Climatic changes; North America; Congresses

121 NAL Call No: 340.8 AG8
Crop responses to carbon dioxide doubling: a literature survey.
Cure, J.D.; Acock, B.
Amsterdam : Elsevier Science Publishers; 1986 Oct.
Agricultural and forest meteorology v. 38 (1/3): p. 127-145; 1986 Oct. Includes references.

Language: English

Descriptors: Crop yield; Carbon dioxide; Crop sensitivity; Atmosphere; Water stress

122 NAL Call No: QC981.8.C5W66 1986
Current issues in atmospheric change summary and conclusions of a workshop, October 30-31, 1986.
Nordhaus, William D.
National Research Council (U.S.), Board on Atmospheric Sciences and Climate, National Research Council (U.S.), Commission on Physical Sciences, Mathematics, and Resources
Workshop on Atmospheric Change 1986 : Washington, D.C.
Washington, D.C. : National Academny Press; 1987, reprinted 1987.
ix, 39 p. : ill. ; 23 cm. Chairman: William D. Nordhaus. "PB88-114335" on cover. Includes bibliographical references (p. 29).

Language: English

Descriptors: Climatic changes; Congresses; Atmospheric ozone; Reduction; Congresses

123 NAL Call No: S544.3.V8V53
A dendrochronological study of drought in the Hudson Valley, New York.
Cook, E.R.

Blacksburg, Va. : The School; 1981 Aug.
FWS - Virginia Polytechnic Institute and State University, School of Forestry and Wildlife Resources (2-80): p. 133-141. maps; 1981 Aug. Paper presented at the Conference on "Dendrology in the Eastern Deciduous Biome," September 11-13, 1979, Blacksburg, Virginia. Includes references.

Language: English

Descriptors: New York; Forests; Annual rings; Drought; Dendroclimatology; Climatic change

124 NAL Call No: QC879.8.D47
Detecting the climatic effects of increasing carbon dioxide.
MacCracken, Michael C.; Luther, F. M.
Washington, D.C. : U.S. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division ; Springfield, Va. : Available from National Technical Information Service, U.S. Dept. of Commerce; 1985.
xxviii, 198 p. : ill. ; 28 cm. December 1985. DOE/ER-0235. Dist. category UC-11. Includes bibliographies and indexes.

Language: English

Descriptors: Atmospheric carbon dioxide; Climatic changes

125 NAL Call No: 292.8 W295
The development and testing of a water balance model for climate impact assessment: modeling the Sacramento Basin.
Gleick, P.H.
Washington, D.C. : American Geophysical Union; 1987 Jun.
Water resources research v. 23 (6): p. 1049-1061. maps; 1987 Jun. Includes references.

Language: English

Descriptors: California; Water balance; Water availability; Climatic change; Hydrology; Runoff; Soil moisture

126 NAL Call No: aQK751.U7 1988
Direct responses of forest trees to rising atmospheric carbon dioxide.
Norby, R.J.
Broomall, PA : Northeastern Forest Experiment Station, [1989?]; 1989 Sep.
Air pollution effects on vegetation, including forest ecosystems : proceedings of the Second US-USSR Symposium / edited by Reginald D. Noble, Juri L. Martin, and Keith F. Jensen. p. 243-249; 1989 Sep. Papers presented at an International Conference, September 13-25, 1988, at Corvallis, Oregon; Raleigh, North Carolina; Gatlinburg, Tennessee. Includes references.

Language: English

Descriptors: Forest trees; Carbon dioxide; Responses; Climatic change

127 NAL Call No: QH344.G562
Diurnal CO2 exchange and photosynthesis of the Samoa tropical forest.
Ryan, S.
Washington, D.C. : American Geophysical Union; 1990 Mar.
Global biogeochemical cycles v. 4 (1): p. 69-84. maps; 1990 Mar. Includes references.

Language: English

Descriptors: American samoa; Tropical forests; Carbon dioxide; Gas exchange; Photosynthesis; Respiration; Weather; Wind

128 NAL Call No: QK710.P55
Does climatic warming increase the risk of frost damage in northern trees?
Hanninen, H.
Oxford : Blackwell Scientific Publications; 1991 Jun.
Plant, cell and environment v. 14 (5): p. 449-454; 1991 Jun. Includes references.

Language: English

Descriptors: Finland; Forest trees; Buds; Budding; Plant development; Timing; Frost injury; Risk; Phenology; Dormancy; Climatic change; Air temperature; Simulation models; Computer simulation; Boreal forests; Carbon dioxide enrichment

129 NAL Call No: KF26.E55 1989
DOE's national energy plan and global warming hearing before the Committee on Energy and Natural Resources, United States Senate, One Hundred First Congress, first session ... July 26, 1989.
United States. Congress. Senate. Committee on Energy and Natural Resources
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.En 2:S.hrg.101-235.
iii, 155 p. : ill. ; 24 cm. (S. hrg. ; 101-235). Distributed to some depository libraries in microfiche. Includes bibliographical references (p. 69).

Language: English

Descriptors: Climatic changes; United States; Energy policy; United States; Global warming

130 NAL Call No: SB123.3.C57
Ecological effects of climate change on plant populations and vegetation composition with particular reference to the British flora.
Grime, J.P.
New York : Belhaven Press; 1990.
Climatic change and plant genetic resources / edited by M.T. Jackson, B.V. Ford-Lloyd, M.L. Parry. p. 40-60. maps; 1990. Literature review. Includes references.

Language: English

Descriptors: Great Britain; Climatic change; Carbon dioxide; Botanical composition; Phenology; Plant ecology; Plant succession; Vegetation types; Literature reviews

131 NAL Call No: QC981.8.C5E4
Economic and social measures of biologic and climatic change final report.
United States, Dept. of Transportation, Panel on Economic and Social Measures of Biologic and Climatic Change
Arlington, Va. : Institute for Defense Analysis, Science and Technology Division, [1975?]; 1976.
1 v. (various pagings) : ill. (CIAP monograph : 6). September 1975. Prepared for Department of Transportation, Climatic Impact Assessment Program, Office of the Secretary of Transportation. DOT-TST-75-56. PB 247 72. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Social aspects; Climatic changes; Economic aspects; Air; Pollution; Stratosphere; Air quality management

132 NAL Call No: HC603.5.A4
An economic perspective on the greenhouse effect.
Haynes, J.; Fisher, B.S.; Jones, B.P.
Canberra : Australian Bureau of Agricultural and Resource Economics; 1990 Sep.
Agriculture & resoures quarterly v. 2 (3): p. 307-316; 1990 Sep. Includes references.

Language: English

Descriptors: Climatic change; Energy conservation; Environmental protection

133 NAL Call No: QC980.C55
The effect of changing climate on Australian biomass production: a preliminary study.
Pittock, A.B.; Nix, H.A.
Dordrecht : D. Reidel Pub. Co; 1986 Jun.
Climatic change v. 8 (3): p. 243-255. maps; 1986 Jun. Includes references.

Language: English

Descriptors: Australia; Biomass determination; Climatic change; Rain; Fluctuations; Carbon dioxide; Historical records; Projections; Models; Infrared radiation; Plant damage

134 NAL Call No: 472 N21
Effect of climate change on fire regimes in northwestern Minnesota.
Clark, J.S.
London : Macmillan Magazines Ltd; 1988 Jul21.
Nature v. 334 (6179): p. 233-235; 1988 Jul21. Includes references.

Language: English

Descriptors: Minnesota; Forest fires; Forest ecology; Climatic change

135 NAL Call No: QH540.N3
The effect of enhanced solar UV-B radiation on motile microorganisms.
Hader, D.P.
Berlin, W. Ger. : Springer-Verlag; 1986.
N.A.T.O. A.S.I (Advanced Study Institute) series. Series G. Ecological sciences v. 8: p. 223-233. ill; 1986. Paper presented at the "Workshop on The Impact of Solar Ultraviolet Radiation upon Terrestial Ecosystems: 1. Agricultural Crops," Sept 27-30, 1983, Windsheim, West Germany. Includes references.

Language: English

Descriptors: Dictyostelium; Euglena gracilis; Phormidium uncinatum; Ultraviolet radiation; Development; Motility; Phototaxis; Solar radiation

136 NAL Call No: QH344.G562
Effect of model structure on the response of terrestrial biosphere models to CO2 and temperature increases.
Harvey, L.D.D.
Washington, D.C. : American Geophysical Union; 1989 Jun.
Global biogeochemical cycles v. 3 (2): p. 137-153;

1989 Jun. Includes references.

Language: English

Descriptors: Atmosphere; Air temperature; Carbon cycle; Carbon dioxide; Detritus; Ecosystems; Photosynthesis; Respiration; Soil biology; Simulation models

137 **NAL Call No: S601.A34**
Effects of atmospheric CO2 enrichment on plant growth: the interactive role of air temperature.
Idso, S.B.; Kimball, B.A.; Anderson, M.G.; Mauney, J.R.
Amsterdam : Elsevier; 1987 Nov.
Agriculture, ecosystems and environment v. 20 (1): p. 1-10; 1987 Nov. Includes references.

Language: English

Descriptors: Arizona; Daucus carota; Raphanus sativus; Eichhornia crassipes; Azolla pinnata; Carbon dioxide enrichment; Air temperature; Growth rate

138 **NAL Call No: QC988.A66G4**
Effects of change in land use on climate in the humid tropics.
Henderson-Sellers, A.
New York : John Wiley for the United Nations University; 1987.
The Geophysiology of Amazonia : vegetation and climate interactions / Robert E. Dickinson, editor. p. 463-493; 1987. Literature review. Includes references.

Language: English

Descriptors: Brazil; Climate; Climatic change; Deforestation; Forest influences; Human activity; Humid tropics; Land use; Models; Precipitation; Rain; Statistical analysis; Tropical rain forests

139 **NAL Call No: SB123.3.C57**
Effects of changes in climate and physiology around the dry limits of agriculture in the tropics.
Squire, G.R.
New York : Belhaven Press; 1990.
Climatic change and plant genetic resources / edited by M.T. Jackson, B.V. Ford-Lloyd, M.L. Parry. p. 116-147; 1990. Literature review. Includes references.

Language: English

Descriptors: Climatic change; Dry conditions; Agropastoral systems; Genotypes; Plant breeding; Plant physiology; Tropics; Literature reviews

140 **NAL Call No: QH540.E23**
The effects of climate change on decomposition processes in grassland and coniferous forests.
Anderson, I.M.
Tempe, Ariz. : Ecological Society of America; 1991 Aug.
Ecological applications v. 1 (3): p. 326-347; 1991 Aug. Includes references.

Language: English

Descriptors: Climatic change; Coniferous forests; Grasslands; Decomposition; Carbon dioxide; Organic matter; Humus; Temperature; Tundra

141 **NAL Call No: 290.9 AM3PS (IR)**
Effects of climate change on U.S. irrigation.
Peterson, D.F.; Keller, A.A.
New York, N.Y. : American Society of Civil Engineers; 1990 Mar.
Journal of irrigation and drainage engineering v. 116 (2): p. 194-210; 1990 Mar. Includes references.

Language: English

Descriptors: U.S.A.; Irrigation; Irrigation requirements; Climatic change; Precipitation; Evapotranspiration; Carbon dioxide

142 **NAL Call No: 292.9 AM34**
Effects of climatic change on the Thornthwaite moisture index.
McCabe, G.J. Jr; Wolock, D.M.; Hay, L.E.; Ayers, M.A.
Minneapolis, Minn. : American Water Resources Association; 1990 Aug.
Water resources bulletin v. 26 (4): p. 633-643. maps; 1990 Aug. Includes references.

Language: English

Descriptors: U.S.A.; Water balance; Climatic change; Temperature; Precipitation; Carbon dioxide; Evapotranspiration; Drought; Indexes

143 **NAL Call No: 450 AN7**
The effects of elevated concentrations of carbon dioxide on individual plants, populations, communities and ecosystems.
Woodward, F.I.; Thompson, G.B.; McKee, I.F.
London : Academic Press; 1991 Jun.
Annals of botany v. 67 (suppl.1): p. 23-38; 1991 Jun. Literature review. Includes references.

Language: English

Descriptors: Plant physiology; Carbon dioxide; Enrichment; Growth; Plant ecology; Plant communities; Ecosystems; Climatic change; Literature reviews

Abstract: Changes in the atmospheric concentration of CO2, over periods of millennia, are positively correlated with the temperature of the world. It is expected that this positive correlation will be manifested in the future, warmer 'greenhouse world' with higher concentrations of CO2. The predicted changes in temperature and precipitation are expected to cause significant changes in the distribution patterns of the world's terrestrial vegetation (Woodward and McKee, 1991). In addition to this indirect effect, CO2 influences plants directly and an increase in the concentration of CO2 may increase the rate of photosynthesis in plants with the C3 pathway of fixation. Experimental observations often differ in the degree and length of this stimulation, reflecting the stronger impact of other photosynthetic limitations. Where photosynthetic stimulation does occur there is a general decrease in leaf protein, which may stimulate rates of leaf herbivory. The well established and associated increase in the C/N ratio of individual leaves should reduce rates of leaf decomposition. However the few community experiments at elevated CO2 suggest little change in the rate of nutrient cycling in communities. Stomatal opening is generally reduced as CO2 concentration increases. This feature scales up through to the community level, however, it appears that the total volume of water used by a community is unlikely to alter with CO2 alone, because plants tend to develop leafier canopies. This change, plus enhanced rates of root development, indicate a greater potential for carbon sequestration by terrestrial ecosystems. Monthly observations of atmospheric CO2 concentration above the tundra over the last 14 years indicate these expected increases in the rates of CO2 drawdown by the northern ecosystems of the tundra and the boreal and temperate deciduous forests. However, some of this change may be due to interactions with the warmer climate of the 1980s and perhaps an increased aerial supply o

144 NAL Call No: QH540.N3
Effects of enhanced ultraviolet-B radiation on yield and disease incidence and severity for wheat under field conditions.
Biggs, R.H.; Webb, P.G.
Berlin, W. Ger. : Springer-Verlag; 1986.
N.A.T.O. A.S.I (Advanced Study Institute) series. Series G. Ecological sciences v. 8: p. 303-311; 1986.
Paper presented at the "Workshop on The Impact of Solar Ultraviolet Radiation upon Terrestial Ecosystems: 1. Agricultural Crops," Sept 27-30, 1983, Windsheim, West Germany. Includes references.

Language: English

Descriptors: Triticum aestivum; Ultraviolet radiation; Crop yield; Cochliobolus sativus; Puccinia recondita; Leptosphaeria nodorum; Ozone; Reduction; Biomass accumulation; Cultivars; Varietal susceptibility

145 NAL Call No: QK710.P55
The effects of increased atmospheric carbon dioxide and temperature on carbon partitioning, source-sink relations and respiration.
Farrar, J.F.; Williams, M.L.
Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 819-830; 1991 Oct. Literature review. Includes references.

Language: English

Descriptors: Plants; Carbon dioxide enrichment; Air temperature; Photosynthates; Source sink relations; Sucrose; Starch; Dry matter distribution; Respiration; Literature reviews

146 NAL Call No: QK710.P55
The effects of increasing CO2 on crop photosynthesis and productivity: a review of field studies.
Lawlor, D.W.; Mitchell, R.A.C.
Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 807-818; 1991 Oct. Literature review. Includes references.

Language: English

Descriptors: Crops; Photosynthesis; Carbon dioxide enrichment; Biomass production; Water use efficiency; Crop yield; Dry matter accumulation; Dry matter distribution; Field experimentation; Literature reviews

147 NAL Call No: 450 R11
Effects of supplemental ultraviolet-B radiation on the growth and physiology of field-grown soybean.
Murali, N.S.; Teramura, A.H.
Oxford : Pergamon Journals; 1986 Jul.
Environmental and experimental botany v. 26 (3): p. 233-242; 1986 Jul. Includes references.

Language: English

Descriptors: Glycine max; Ultraviolet radiation; Growth; Climatic factors; Varietal reactions

148 NAL Call No: QH540.N3
Effects of ultraviolet-B radiation on the growth and productivity of field grown soybean.
Lydon, J.; Teramura, A.H.; Summers, E.G.
Berlin, W. Ger. : Springer-Verlag; 1986.
N.A.T.O. A.S.I (Advanced Study Institute) series. Series G. Ecological sciences v. 8: p. 313-325; 1986. Paper presented at the "Workshop on The Impact of Solar Ultraviolet Radiation upon Terrestial Ecosystems: 1. Agricultural Crops," Sept 27-30, 1983, Windsheim, West Germany. Includes references.

Language: English

Descriptors: Glycine max; Ultraviolet radiation; Growth rate; Solar radiation; Biomass accumulation; Cultivars; Leaf area

149 NAL Call No: QH540.N3
Effects of UV-B radiation on photosynthesis.
Sisson, W.B.
Berlin, W. Ger. : Springer-Verlag; 1986.
N.A.T.O. A.S.I (Advanced Study Institute) series. Series G. Ecological sciences v. 8: p. 161-169; 1986. Paper presented at the "Workshop on The Impact of Solar Ultraviolet Radiation upon Terrestial Ecosystems: 1. Agricultural Crops," Sept 27-30, 1983, Windsheim, West Germany. Literature review. Includes references.

Language: English

Descriptors: Photosynthesis; Ultraviolet radiation; Ozone; Reduction; Chlorophyll; Chloroplasts; Membranes; Acclimatization; Tolerances

150 NAL Call No: 410 EC7
Elevated atmospheric CO2 effects on belowground processes in C3 and C4 estuarine march communities.
Curtis, P.S.; Balduman, L.M.; Drake, B.G.; Whigham, D.F.
Tempe, Ariz. : The Society; 1990 Oct.
Ecology : a publication of the Ecological Society of America v. 71 (5): p. 2001-2006; 1990 Oct. Includes references.

Language: English

Descriptors: Maryland; Scirpus; Spartina; Bog plants; Carbon dioxide; Climatic change; Growth; Nitrogen; Plant communities; Rhizomes; Roots; Wetlands

151 NAL Call No: TJ810.A1S6
The empirical relationship between global radiation and global ultraviolet (0.290-0.385) micrometers solar radiation components.
Al-Aruri, S.D.
Elmsford, N.Y. : Pergamon Press; 1990.
Solar energy v. 45 (2): p. 61-64; 1990. Includes references.

Language: English

Descriptors: Kuwait; Solar radiation; Components; Ultraviolet radiation; Measurement

152 NAL Call No: QC981.8.C5U514
Energy and climate change report of the DOE Multi-Laboratory Climate Change Committee.
United States. DOE Multi-Laboratory Climate Change Committee; Lawrence Livermore National Laboratory
Chelsea, Mich. : Lewis Publishers; 1990.
xvi, 161 p. : ill. ; 27 cm. Includes bibliographical references (p. 147-160).

Language: English

Descriptors: Climatic changes; Atmospheric carbon dioxide; Energy consumption

153 NAL Call No: Audiocassette no.155
Energy, global warming & sust [i.e. sustainable] ag [i.e. agriculture] Amory Lovins. (Energy, global warming and sustainable agriculture.)
Lovins, Amory B.,
Committee for Sustainable Agriculture, Audio Productions
Ecological Farmer Conference 1990 : Asilomar, Calif.
Colfax, CA : CSA ; [Seattle, WA : Distributed by] Audio Productions; 1990.
1 sound cassette (ca. 95 min.). At head of title: Ecological Farmer Conference 1990. Presented at the 10th anniversary Ecological Farming Conference, January 12-14, 1990, at Asilomar, Calif. F 710.

Language: English

Descriptors: Global warming; Congresses; Sustainable agriculture; Congresses; Agricultural ecology; Congresses; Agricultural; Energy consumption; Environmental aspects; Congresses

154 NAL Call No: KF27.I5542 1988b
Energy policy implications of global warming hearings before the Subcommittee on Energy and

Power of the Committee on Energy and Commerce, House of Representatives, One Hundredth Congress, second session, July 7 and September 22, 1988.
United States. Congress. House. Committee on Energy and Commerce. Subcommittee on Energy and Power
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.En 2/3:100-229.
iii, 265 p. : ill., maps ; 24 cm. Cover title. Serial no. 100-229. Includes bibliographies.

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric; United States; Atmospheric carbon dioxide; Environmental aspects; United States

155 NAL Call No: S600.7.C54E87
Estimating effects of climatic change on agriculture in Saskatchewan, Canada.
Williams, G. Daniel V.
Laxenburg, Austria : International Institute for Applied Systems Analysis ; [S.l.] : United Nations Environment Programme; 1987.
v, 147 p. : ill. ; 30 cm. Preprinted from: M.L. Parry, T.R. Carter, and N.T. Konijn (Eds) (1987), The impact of climatic variations on agriculture. Volume 1. Assessments in cool temperate and cold regions (Reidel, Dordrecht, The Netherlands). Includes bibliographical references (p. 104-112).

Language: English

Descriptors: Climatic changes; Saskatchewan; Agriculture; Saskatchewan; Crops and climate; Saskatchewan; Agricultural estimating and reporting; Saskatchewan; Agriculture and state; Saskatchewan

156 NAL Call No: SD13.C35
Estimating the effects of land-use change on global atmospheric CO2 concentrations.
Dale, V.H.; Houghton, R.A., Hall, C.A.S.
Ottawa, Ont. : National Research Council of Canada; 1991 Jan.
Canadian journal of forest research; Journal canadien de recherche forestiere v. 21 (1): p. 87-90; 1991 Jan. Includes references.

Language: English

Descriptors: Asia; Climatic change; Temperature; Carbon dioxide; Land use; Land clearance

157 NAL Call No: NBUQC980 E9 1989
Europhysics Study Conference on Induced Critical Conditions in the Atmosphere, Torino, Italy, 27-30 September 1989. (Induced critical conditions in the atmosphere.)
Tartaglia, A.; Vadacchino, M.
Europhysics Study Conference on Induced Critical Conditions in the Atmosphere 1989 : Torino, Italy.
Singapore ; Teaneck, New Jersey : World Scientific; 1990.
x, 280 p. : ill. ; 23 cm. Spine title: Induced critical conditions in the atmosphere.

Language: English

Descriptors: Climatology; Nuclear winter; Ozone layer depletion; Greenhouse effect, Atmospheric

158 NAL Call No: SD390.7.G73G74
Evidence for future warming: how large and when?
Hansen, J.; Lacis, A.; Rind, D.; Russell, G.; Fung, I.; Lebedeff, S.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 57-75. maps; 1987. Includes references.

Language: English

Descriptors: Climatic change; Models; Thermal radiation; Prediction; Carbon dioxide; Ozone; World problems

159 NAL Call No: QH541.5.S3E97
Expected effects of climatic change on marine coastal ecosystems.
Beukema, Jan J.,1935-; Wolff, W. J.; Brouns, Joop J. W. M.,
Dordrecht ; Boston : Kluwer Academic; 1990.
221 p. : ill. ; 27 cm. (Developments in hydrobiology ; 57). Papers from an international workshop held on Texel, the Netherlands, Nov. 11-15, 1988. Includes bibliographical references.

Language: English

Descriptors: Marine ecology; Coastal ecology; Climatic changes

160 NAL Call No: SD390.6.C2E86
An Exploration and assessment of the implications of climatic change for the boreal forest and forestry economics of the Prairie Provinces and Northwest Territories phase one.
Wheaton, E. E.

Canada, Atmospheric Environment Service, Saskatchewan Research Council
Saskatoon, Saskatchewan : Saskatchewan Research Council; 1987.
xxxii, 282 p. : ill., maps ; 28 cm. (SRC technical report ; no. 211). Under contract with the Atmospheric Environment Service, Environment Canada, DSS contract no. 02SE.KM111-6-6330. November, 1987. SRC publication no. E-906-36-B-87. Bibliography: p. 213-235.

Language: English

Descriptors: Forest meteorology, Canada; Greenhouse effect, Atmospheric, Canada; Climatic changes, Economic aspects, Canada; Forest influences, Canada; Forests and forestry, Economic aspects, Canada

161 **NAL Call No: 501 L84B**
An exploratory model of the impact of rapid climate change on the world food situation.
Daily, G.C.; Ehrlich, P.R.
London : The Society; 1990 Sep22.
Proceedings of the Royal Society of London : Series B : Biological sciences v. 241 (1302): p. 232-244; 1990 Sep22. Includes references.

Language: English

Descriptors: Climatic change; Famine; Food supply; Human population; Population growth; Simulation models; Starvation; World food problems

162 **NAL Call No: QC912.3.W34**
Farming in the greenhouse what global warming means for American agriculture.
Ward, Justin R.; Hardt, Richard A.; Kuhnle, Thomas E.
Natural Resources Defense Council
Washington, D.C. : Natural Resources Defense Council; 1989.
viii, 33 p. : ill., maps ; 28 cm. March 1989. Includes bibliographical references.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global temperature changes; Meteorology, Agricultural

163 **NAL Call No: Z699.F64**
Focus on global change. (Focus on global change Global change.)
Institute for Scientific Information
Philadelphia, PA : Institute for Scientific Information, 1990-; 1990-9999.
computer disks ; 5 1/4 in. + user guide. Description based on: Vol. 1, no. 3 (April 2, 1990); title from disk label. User guide includes index.

Language: English

Descriptors: Global temperature changes; Periodicals; Bibliography; Data bases; Global warming; Periodicals; Bibliography; Data bases

164 **NAL Call No: 292.8 W295**
Foliage temperature: effects of environmental factors with implications for plant water stress assessment and the CO2/climate connection.
Idso, S.B.; Clawson, K.L.
Washington, D.C. : American Geophysical Union; 1986 Nov.
Water resources research v. 22 (12): p. 1702-1716; 1986 Nov. Includes references.

Language: English

Descriptors: Arizona; Eichhornia crassipes; Medicago sativa; Gossypium hirsutum; Foliage; Temperatures; Transpiration; Water stress; Carbon dioxide; Climate; Climatic change

165 **NAL Call No: QC988.A66G4**
The forest and the hydrological cycle.
Salati, E.
New York : John Wiley for the United Nations University; 1987.
The Geophysiology of Amazonia : vegetation and climate interactions / Robert E. Dickinson, editor. p. 273-296. ill., maps; 1987. Includes references.

Language: English

Descriptors: Brazil; Climatic change; Deforestation; Forest influences; Humid tropics; Hydrological cycle; Precipitation; River basins; Solar radiation; Water balance; Water vapor

166 **NAL Call No: QH545.A1E52**
Forest responses to tropospheric ozone and global climate change: an analysis.
Kickert, R.N.; Krupa, S.V.
Essex : Elsevier Applied Science; 1990.
Environmental pollution v. 68 (1/2): p. 29-65. maps; 1990. Literature review. Includes references.

Language: English

Descriptors: Ozone; Forests; Climatic change; Ecosystems; Responses; Literature reviews

167 **NAL Call No: SD390.7.G73G74**

Forestry research needs and strategies.
Lee, J.C.; Kramer, P.J.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 295-302; 1987.

Language: English

Descriptors: Forestry; Research projects; Planning of research; Climatic change; Carbon dioxide; Economic factors

168 NAL Call No: 99.8 F768
Forests to offset the greenhouse effect.
Sedjo, R.A.
Bethesda, Md. : Society of American Foresters; 1989 Jul.
Journal of forestry v. 87 (7): p. 12-15. ill., maps; 1989 Jul. Includes references.

Language: English

Descriptors: Climatic change; Afforestation; Forest plantations; Carbon dioxide

169 NAL Call No: TD885.5.C3F8
Future atmospheric carbon dioxide scenarios and limitation strategies.
Edmonds, J. A.
Park Ridge, N.J., U.S.A. : Noyes Publications; 1986.
xx, 620 p. : ill. ; 25 cm. Includes bibliographies.

Language: English

Descriptors: Atmospheric carbon dioxide, Environmental aspects, North America; Fossil fuels, Environmental aspects, North America; Climatic changes, North America; Corn, North America, Climatic factors

170 NAL Call No: SD390.5.F6 1985
Gas exchange between forest and atmosphere.
Murphy, C.E. Jr
Washington, D.C. : U.S. Dept. of Energy; 1987 May.
Proceedings of the Forest-Atmosphere Interaction Workshop, Lake Placid, New York, October 1-4, 1985 / coordinated and edited by Harry Moses ... [et al.]. p. 147-181. ill; 1987 May. Includes references.

Language: English

Descriptors: Forest trees; Canopy; Gas exchange; Diffusion; Atmosphere; Leaves; Carbon dioxide; Water vapor; Sulfur dioxide; Soils; Diurnal variation

171 NAL Call No: TD885.5.C3N3
Glaciers, ice sheets, and sea level effect of a CO2-induced climatic change : report of a workshop held in Seattle, Washington, September 13-15, 1984.
National Research Council (U.S.). Ad Hoc Committee on the Relationship Between Land Ice and Sea Level; United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Springfield, Va. : Available from the National Technical Information Service; 1985.
xiii, 330 p. : ill. , maps ; 28 cm. DOE/ER/60235-1. September 1985. Prepared for United States Department of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division. Includes bibliographies.

Language: English

Descriptors: Carbon dioxide; Environmental aspects; Congresses; Climatic changes; Congresses; Glaciers; Congresses; Ice; Congresses; Sea level; Congresses

172 NAL Call No: 99.8 F768
The global carbon cycle.
Sedjo, R.A.
Bethesda, Md. : Society of American Foresters; 1990 Oct.
Journal of forestry v. 88 (10): p. 33-34; 1990 Oct. Includes references.

Language: English

Descriptors: Climatic change; Carbon; Land use; Forests

173 NAL Call No: QH545.A1E52
The global carbon cycle and climate change: responses and feedbacks from below-ground systems.
Dixon, R.K.; Turner, D.P.
Essex : Elsevier Applied Science; 1991.
Environmental pollution v. 73 (3/4): p. 245-262; 1991. Special issue on "Plant Response to Atmospheric Change". Includes references.

Language: English

Descriptors: Carbon; Cycling; Climatic change; Carbon dioxide; Soil; Vegetation types; Nutrient content

174 NAL Call No: QC903.G5
Global change.
International Geosphere-Biospherc Program "Global Changes.",Secretariat
Stockholm : IGBP Secretarial, 1986-; 1986-9999.
Global change - IGBP. v. ; 30 cm; 1986-9999.

Language: English

Descriptors: Global temperature changes; Climatic changes

175 NAL Call No: Q180.U5A4 1989
Global change 1989 40th Arctic Science Conference, Fairbanks, Alaska : proceedings, September 14-16, 1989.
Arctic Science Conference 1989 : Fairbanks, Alaska); American Association for the Advancement of Science, Arctic Division, University of Alaska, Fairbanks, Institute of Arctic Biology
Fairbanks, Alaska : Arctic Division, American Association for the Advancement of Science and Institute of Arctic Biology, University of Alaska Fairbanks; 1989.
v, 65 p. ; 28 cm. Includes index.

Language: English

Descriptors: Climatic changes; Global temperature changes

176 NAL Call No: HC79.E5G56
Global change and our common future papers from a forum.
DeFries, Ruth S.; Malone, Thomas F.
National Research Council (U.S.), Committee on Global Change
Forum on Global Change and Our Common Future 1989 : Washington, D.C.
Washington, D.C. : National Academy Press; 1989.
xiii, 227 p. : ill., maps ; 28 cm. Committee on Global Change, National Research Council. Proceedings of the Forum on Global Change and Our Common Future, held on May 2-3, 1989, at the National Theatre in Washington, D.C., and organized by the the National Research Council's Committee on Global Change. Includes bibliographical references.

Language: English

Descriptors: Environmental policy; Pollution; Human ecology; Global warming

177 NAL Call No: 450 AN7
Global change and the biosphere: introduction.
Chaloner, W.G.
London : Academic Press; 1991 Jun.
Annals of botany v. 67 (suppl.1): p. 1-3; 1991 Jun. Includes references.

Language: English

Descriptors: Uk; Climatic change; Pollution; Environmental factors; Ozone; Weather; Research projects

178 NAL Call No: KF27.S3978 1989h
The Global Change Research Act of 1989 hearing before the Subcommittee on Natural Resources, Agriculture Research, and Environment and the Subcommittee on International Scientific Cooperation of the Committee on Science, Space, and Technology, House of Representatives, One Hundred First Congress, first session, July 27, 1989.
United States. Congress. House. Committee on Science, Space, and Technology. Subcommittee on Natural Resources, Agriculture Research, and Environment; United States, Congress, House, Committee on Science, Space, and Technology, Subcommittee on International Scientific Cooperation
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1990; Y 4.Sci 2:101/74.
iii, 280 p. : ill. ; 24 cm. Distributed to some depository libraries in microfiche. No. 74.

Language: English

Descriptors: Climatic changes; Research; United States; Global temperature changes; Research; United States

179 NAL Call No: KF26.C6 1988
Global change research hearing before the Committee on Commerce, Science, and Transportation, United States Senate, One Hundredth Congress, second session, on global change research and S. 2614 ... July 13, 1988.
United States. Congress. Senate. Committee on Commerce, Science, and Transportation
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1988; Y 4.C 73/7:S.hrg.100-816.
iii, 94 p. : ill. ; 24 cm. (S. hrg. ; 100-816). Distributed to some depository libraries in microfiche. Shipping list no.: 88-689-P.

Language: English

Descriptors: Climatic changes, Research, United States; Rainfall anomalies, Research, United

States; Greenhouse effect, Atmospheric, Research, United States

180 **NAL Call No: 450 IS7**
Global change: vegetation, ecosystems, and land use in the southern Mediterranean Basin by the mid twenty-first century.
Le Houerou, H.N.
Jerusalem, Israel : Weizmann Science Press of Israel; 1990.
Israel journal of botany v. 39 (4/6): p. 481-508. maps; 1990. Paper published in "Germination Physiology and Desert Ecology", a special edition dedicated to Professor Michael Evenari. Includes references.

Language: English

Descriptors: Mediterranean countries; Middle east; Climatology; Temperature; History; Plant community analysis; Vegetation sampling; Natural distribution; Environmental degradation; Land use; Population growth

181 **NAL Call No: KF26.O3 1989**
Global change, an ocean perspective hearing before the National Ocean Policy Study of the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred First Congress, first session ... April 11, 1989. (Global change, an ocean perspective.)
United States. Congress. Senate. National Ocean Policy Study
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.C 73/7:S.hrg.101-95.
iii, 81 p. : ill. ; 24 cm. (S. hrg. ; 101-95). Distributed to some depository libraries in microfiche. Bibliography: p. 54-55.

Language: English

Descriptors: Ocean-atmosphere interaction; Climatic changes; Oceanography; United States

182 **NAL Call No: TD419.R47**
Global climate change and acidic deposition.
Nikolaidis, N.P.; Ecsedy, C.; Nikolaidis, V.S.; Olem, H.; Saldi, K.; Tarbox, S.
Alexandria, Va. : The Federation; 1991 Jun.
Research journal of the Water Pollution Control Federation v. 63 (4): p. 735-746; 1991 Jun. Includes references.

Language: English

Descriptors: Air pollution; Climatic change; Acid deposition; Models; Reviews

183 **NAL Call No: QC903.G8 1988**
Global climate change and the greenhouse effect congressional activity and options.
Gushee, David E.
Library of Congress, Congressional Research Service
Washington, D.C. : Major Issues System, Congressional Research Service, Library of Congress; 1988.
14 p. ; 28 cm. (CRS issue brief). Cover title. Updated November 2, 1988. Bibliography: p. 14.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global temperature changes; Climatic changes; Research; United States

184 **NAL Call No: 472 N21**
Global climate change and US agriculture.
Adams, R.M.; Rosenzweig, C.; Peart, R.M.; Ritchie, J.T.; McCarl, B.A.; Glyer, J.D.; Curry, R.B.; Jones, J.W.; Boote, K.J.; Allen, L.H. Jr
London : Macmillan Magazines Ltd; 1990 May17.
Nature v. 345 (6272): p. 219-224. maps; 1990 May17. Includes references.

Language: English

Descriptors: Agricultural production; Agricultural economics; Climatic change; Carbon dioxide; Crop yield

Abstract: Agricultural productivity is expected to be sensitive to global climate change. Models from atmospheric science, plant science and agricultural economics are linked to explore this sensitivity. Although the results depend on the severity of climate change and the compensating effects of carbon dioxide on crop yields, the simulation suggests that irrigated acreage will expand and regional patterns of US agriculture will shift. The impact on the US economy strongly depends on which climate model is used.

185 **NAL Call No: KF26.A6486 1990**
Global climate change hearing before a subcommittee of the Committee on Appropriations, United States Senate, One Hundred First Congress, second session : special hearing.
United States. Congress. Senate. Committee on Appropriations. Subcommittee on HUD-Independent Agencies
Washington : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.;

1990; Y 4.Ap 6/2:S.hrg.101-965.
iii, 108 p. : ill. ; 24 cm. (S. hrg. ; 101-965). "Fiscal year 1991", Cover. Distributed to some depository libraries in microfiche.

Language: English

Descriptors: Climatic changes; Global warming

186 NAL Call No: KF27.M473 1989a
Global climate change hearing before the Subcommittee on Oceanography and the Great Lakes of the Committee on Merchant Marine and Fisheries, House of Representatives, One Hundred First Congress, first session, on H.R. 980 ... May 4, 1989.
United States. Congress. House. Committee on Merchant Marine and Fisheries. Subcommittee on Oceanography and the Great Lakes
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.M 53:101-15.
iii, 165 p. : ill. ; 24 cm. Distributed to some depository libraries in microfiche. Shipping list no.: 89-539-P. Serial no. 101-15. Includes bibliographical references.

Language: English

Descriptors: Greenhouse effect, Atmospheric; United States; Global temperature changes; Environmental law; United States; Environmental policy; United States

187 NAL Call No: KF27.F645 1989b
Global climate change hearing before the Subcommittees on Human Rights and International Organizations of the Committee on Foreign Affairs, House of Representatives, One Hundred First Congress, first session, October 26, 1989.
United States. Congress. House. Committee on Foreign Affairs. Subcommittee on Human Rights and International Organizations
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1990; Y 4.F 76/1:G 51/5.
iii, 109 p. : ill. ; 24 cm. Distributed to some depository libraries in microfiche. Shipping list no.: 90-205-P. Includes bibliographical references (p. 102-103).

Language: English

Descriptors: Climatic changes; Global temperature changes; Environmental protection; Research; United States; Conservation of natural resources; International cooperation

188 NAL Call No: HD1761.U17
Global climate change holds problems and uncertainties for agriculture.
Rosenberg, N.J.
Washington, D.C. : National Center for Food and Agric Policy, Resources for the Future; 1988.
U.S. agriculture in a global setting : an agenda for the future / M. Ann Tutwiler, editor. p. 203-218. maps; 1988. Includes references.

Language: English

Descriptors: U.S.A.; Agricultural meteorology; Climatic change; Crop yield; Agricultural policy

189 NAL Call No: QC981.8.C5G66
Global climate change human and natural influences.
Singer, S. Fred
New York, N.Y. : Paragon House Publishers; 1989.
vii, 424 p. : ill. ; 24 cm. An ICUS book. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Man; Influence on nature

190 NAL Call No: aSD11.U57
Global climate change: implications for silviculture and pest management.
Hedden, R.L.
New Orleans, La. : The Station; 1989.
General technical report SO - U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station (74): p. 555-562; 1989. Paper presented at the Fifth Biennial Southern Silvicultural Research Conference, Nov 1-3, 1988, Memphis, Tennessee. Includes references.

Language: English

Descriptors: Climatic change; Forestry; Silviculture; Human activity; Carbon dioxide; Insect control; Dendroctonus frontalis

191 NAL Call No: KF26.A35 1989j
Global Climate Change Prevention Act of 1989, S. 1610 hearing before the Committee on Agriculture, Nutrition, and Forestry, United States Senate, One Hundred First Congress, first session, on S. 1610 ... November 6, 1989.
United States. Congress. Senate. Committee on Agriculture, Nutrition, and Forestry
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S.

G.P.O.; 1991; Y 4.Ag 8/3:S.hrg.101-1135.
iii, 96 p. ; 24 cm. (S. hrg. ; 101-1135). Distributed to some depository libraries in microfiche. Shipping list no.: 91-097-P.

Language: English

Descriptors: Climatic changes; Reforestation; Environmental law; Agricultural laws and legislation

192 **NAL Call No: KF26.C69 1990a**
Global climate change seeking a global consensus : hearing before the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred First Congress, second session ... June 14, 1990.
United States. Congress. Senate. Committee on Commerce, Science, and Transportation
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1990; Y 4.C 73/7:S.hrg.101-842.
iii, 56 p. : ill. ; 24 cm. (S. hrg. ; 101-842). Distributed to some depository libraries in microfiche.

Language: English

Descriptors: Global warming; Global temperature changes; Climatic changes

193 **NAL Call No: KF27.F645 1988**
Global climate changes greenhouse effect : hearing before the Subcommittee on Human Rights and International Organizations of the Committee on Foreign Affairs, House of Representatives, One Hundredth Congress, second session, March 10, 1988.
United States. Congress. House. Committee on Foreign Affairs. Subcommittee on Human Rights and International Organizations
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1988; Y 4.F 76/1:G 51/3.
iii, 147 p. : ill. ; 24 cm. Distributed to some depository libraries in microfiche.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Climatic changes, Environmental aspects; Rainfall anomalies

194 **NAL Call No: QC981.8.C5G5**
Global climate trends and greenhouse gas data federal activities in data collection, archiving, and dissemination : report to the Congress of the United States.
United States, Dept. of Energy, Office of Policy, Planning, and Analysis
Washington, DC : U.S. Dept. of Energy, Office of Environmental Analysis, Deputy Under Secretary for Policy, Planning and Annalysis ; Springfield, Va. : Available from the National Technical Information Service, U.S. Dept. of Commerce; 1990.
1 v. (various pagings) : ill. ; 28 cm. June 1990. DOE/PE-0094P. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Greenhouse effect, Atmospheric; Global warming

195 **NAL Call No: QC981.8.C5C55 1988**
Global climate variations over the past century and the greenhouse effect a report based on the First Climate Trends Workshop, September 7-9, 1988, Washington, D.C.
United States, National Climate Program Office
Climate Trends Workshop 1st : 1988 : Washington, D.C.
Rockville, Md. : National Climate Program Office, [1989?]; 1989.
56 p. : ill., maps ; 28 cm. Cover title. Includes bibliographical references (p. 51-54).

Language: English

Descriptors: Climatic changes; Greenhouse effect, Atmospheric; Global temperature changes

196 **NAL Call No: 470 SCI25**
Global climatic change.
Houghton, R.A.; Woodwell, G.M.
New York, N.Y. : Scientific American, Inc; 1989 Apr.
Scientific American v. 260 (4): p. 36-44. ill., maps; 1989 Apr. Includes references.

Language: English

Descriptors: Climatic change; Carbon dioxide; Methane; Air pollution; Climate control; Atmosphere

197 **NAL Call No: KF26.C697 1987**
Global environmental change research hearing before the Subcommittee on Science, Technology, and Space and the National Ocean Policy Study of the Committee on Commerce, Science, and Transportation, United States Senate, One hundredth Congress, first session, on global climate change due to manmade changes in the earth's atmosphere, July 16, 1987.
United States. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcom-

mittee on Science, Technology, and Space; United States, Congress, Senate, National Ocean Policy Study
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1987; Y 4.C 73/7-S.hrg.100-301.
iii, 152 p. : ill., 1 map ; 24 cm. (S. hrg. ; 100-301). Distributed to some depository libraries in microfiche. Bibliography: p. 152.

Language: English

Descriptors: Climatic changes, Research, United States; Climatology, Research, United States; Atmosphere, Research, United States

198 NAL Call No: KF26.E65 1988c
The Global Environmental Protection Act of 1988 joint hearings before the Subcommittee on Hazardous Wastes and Toxic Substances and the Subcommittee on Environmental Protection of the Committee on Environment and Public Works, United States Senate, One Hundredth Congress, second session, on S. 2666 ... September 14 and 16, 1988.
United States. Congress. Senate. Committee on Environment and Public Works. Subcommittee on Hazardous Wastes and Toxic Substances
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1988; Y 4.P 96/10:S.hrg.100-843.
iv, 415 p. : ill. ; 24 cm. (S. hrg. ; 100-843). Distributed to some depository libraries in microfiche. Includes bibliographies.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Climatic changes; Air, Pollution, Law and legislation, United States; Environmental law, United States

199 NAL Call No: HC55.N3
The global greenhouse effect: economic impacts and policy considerations.
Barbier, E.B.
London : Graham & Trotman; 1989 Feb.
Natural resources forum v. 13 (1): p. 20-32. maps; 1989 Feb. Includes references.

Language: English

Descriptors: Weather patterns; Carbon dioxide; Emission; Air pollution; Methane; Nitrous oxide; Economic impact; Environmental policy; Ozone; Climatic change; Cost benefit analysis

200 NAL Call No: jQC981.8.G56T47
Global warming.
Tesar, Jenny E.
New York : Facts on File; 1991.
111 p., [16] p. of plates : ill. (some col.) ; 24 cm. (Our fragile planet). Includes bibliographical references (p. 108-109) and index.

Language: English

Descriptors: Global warming; Environmental protection

201 NAL Call No: 10 J822
Global warming and crop modelling.
Cochrane, J.
Cambridge : Cambridge University Press; 1990 Oct.
The Journal of agricultural science v. 115 (pt.2): p. 295; 1990 Oct. Includes references.

Language: English

Descriptors: Air temperature; Carbon dioxide; Climatic change; Crop production; Methane; Nitrous oxide; Simulation models

202 NAL Call No: KF27.E55 1989
Global warming and its implications for California hearing before the Committee on Energy and Natural Resources, United States Senate, One Hundred First Congress, first session ... Santa Monica, CA, May 20, 1989.
United States. Congress. Senate. Committee on Energy and Natural Resources
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.En 2:S.hrg.101-65.
iii, 179 p. : ill. ; 24 cm. (S. hrg. ; 101-65). Distributed to some depository libraries in microfiche. Includes bibliographical references.

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric; Climatic changes; California

203 NAL Call No: aZ5071.N3
Global warming and the greenhouse effect: 1979-1988.
Maclean, J.T.
Beltsville, Md. : The Library; 1988 Sep.
Quick bibliography series - U.S. Department of Agriculure, National Agricultural Library (U.S.). (88-73): 22 p.; 1988 Sep. Updates QB 86-82. Bibliography.

Language: English

Descriptors: Air pollution; Air temperature; Climatic change

204 NAL Call No: QC981.8.G56S8
Global warming and the "greenhouse effect" current news and views, a general bibliographic compilation.
Stoss, Frederick W.
Center for Environmental Information (U.S.)
Rochester, N.Y. : Center for Environmental Information, Inc.; 1989.
1 v. (unpaged) ; 28 cm. Caption title. Summer 1989.

Language: English

Descriptors: Global warming; Bibliography; Greenhouse effect, Atmospheric; Bibliography

205 NAL Call No: aZ5071.N3
Global warming and the greenhouse effect, January 1979-February 1990.
MacLean, J.T.
Beltsville, Md. : The Library; 1990 Jun.
Quick bibliography series - U.S. Department of Agriculure, National Agricultural Library (U.S.). (90-56): 31 p.; 1990 Jun. Updates QB 89-96. Bibliography.

Language: English

Descriptors: Climatic change; Carbon dioxide; Air temperature; Bibliographies

206 NAL Call No: aZ5071.N3
Global warming and the greenhouse effect, January 1979-March 1986.
Maclean, J.T.
Beltsville, Md. : The Library; 1986 Sep.
Quick bibliography series - National Agricultural Library (U.S.). (86-82): 14 p.; 1986 Sep. Bibliography.

Language: English

Descriptors: Climate; Carbon dioxide; Atmospheric disturbances

207 NAL Call No: aZ5071.N3
Global warming and the greenhouse effect January 1979-May 1989.
MacLean, J.T.
Beltsville, Md. : The Library; 1989 Aug.
Quick bibliography series - U.S. Department of Agriculure, National Agricultural Library (U.S.). (89-96): 27 p.; 1989 Aug. Updates QB 88-73. Bibliography.

Language: English

Descriptors: Climatic change; Bibliographies; Carbon dioxide

208 NAL Call No: GB651.N3
Global warming and the insurance industry.
Berz, G.A.
Paris : Unesco; 1991.
Nature and resources v. 27 (1): p. 19-28; 1991. Includes references.

Language: English

Descriptors: Air pollution; Climatic change; Natural disasters; Insurance; Losses

209 NAL Call No: 100 C12CAG
Global warming and the Sacramento-San Joaquin Delta.
Logan, S.H.
Oakland, Calif. : Division of Agriculture and Natural Resources, University of California; 1990 May.
California agriculture v. 44 (3): p. 16-18. maps; 1990 May.

Language: English

Descriptors: California; Climatic change; Flooding; Deltas; Simulation models; Damage; Costs

210 NAL Call No: QC981.8.G56S33
Global warming are we entering the greenhouse century?
Schneider, Stephen Henry
San Francisco, CA : Sierra Club Books; 1989.
xiv, 317 p. : ill. ; 24 cm. Includes index. Bibliography: p. [286]-306.

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric; Climatic changes

211 NAL Call No: KF26.5.O3 1989d
Global warming hearing before the National Ocean Policy Study of the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred First Congress, first session ... November 14, 1989.
United States. Congress. Senate. Committee on Commerce, Science, and Transportation. National Ocean Policy Study
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O., 1989 [i.e.; 1990; Y 4.C 73/7:S.hrg.101-559.

iii, 53 p. ; 24 cm. (S. hrg. ; 101-559). Distributed to some depository libraries in microfiche. Shipping list no.: 90-263-P.

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric

212 **NAL Call No: KF26.E678 1985b**
Global warming hearing before the Subcommittee on Toxic Substances and Environmental Oversight of the Committee on Environment and Public Works, United States Senate, Ninety-ninth Congress, first session, December 10, 1985.
United States. Congress. Senate. Committee on Environment and Public Works. Subcommittee on Toxic Substances and Environmental Oversight
Washington, [D.C.] : U.S. G.P.O.; 1986.
iii, 125 p. : 1 map ; 24 cm. (S. hrg. ; 99-503). Distributed to some depository libraries in microfiche. Shipping list no.: 86-326-P. Includes bibliographical references.

Language: English

Descriptors: Global temperature changes; Greenhouse effect, Atmospheric; Climatic changes

213 **NAL Call No: KF27.15542 1989b**
Global warming hearings before the Subcommittee on Energy and Power of the Committee on Energy and Commerce, House of Representatives, One Hundred First Congress, first session, February 21 and May 4, 1989.
United States. Congress. House. Committee on Energy and Commerce. Subcommittee on Energy and Power
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.En 2/3:101-31.
iii, 177 p. : ill. ; 24 cm. Distributed to some depository libraries in microfiche. Serial no. 101-31. Includes bibliographical references.

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric; Energy policy; United States

214 **NAL Call No: SD143.S64**
Global warming: potential causes of future change in U.S. forests.
Woodman, J.N.
Bethesda, Md. : The Society; 1990.
Proceedings of the ... Society of American Foresters National Convention. p. 5-11. maps; 1990. Paper presented at a meeting on "Forestry on the Frontier," Sept 24-27, 1989, Spokane, Washington. Includes references.

Language: English

Descriptors: Climatic change; Carbon dioxide; Forestry; Stand characteristics; Geographical distribution

215 **NAL Call No: QC981.8.G56G58**
Global warming the Greenpeace report.
Leggett, Jeremy K.
Greenpeace UK
Oxford [England] ; New York : Oxford University Press; 1990.
xi, 554 p. : ill. ; 20 cm. Includes index.

Language: English

Descriptors: Global warming; Global warming

216 **NAL Call No: QC912.3.F34 1989**
The greenhouse challenge what's to be done?
Falk, Jim; Brownlow, Andrew
Ringwood, Vic., Australia ; New York, NY, USA : Penguin Books; 1989.
341 p. : ill. ; 20 cm. Includes bibliographical references (p. 284-327) and index.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global warming

217 **NAL Call No: QC981.8.G56T69**
Greenhouse doubts, energy realities a New Zealand perspective.
Toynbee, P. A.
Wellington, N.Z. : Toynbee and Associates; 1990.
53 p. : ill. ; 30 cm. Includes bibliographical references (p. 4) and index.

Language: English

Descriptors: Global warming; Energy conservation; Greenhouse effect, Atmospheric; Atmospheric carbon dioxide

218 **NAL Call No: S1.A375**
The greenhouse effect.
Eberlee, J.
Ottawa : Agrican Publishers, Inc; 1988.
Agrologist v. 17 (4): p. 10-12. ill; 1988.

Language: English

Descriptors: Canada; Climatic change; Environ-

mental impact reporting; Prediction; Projections; Atmospheric disturbances; Carbon dioxide; Land use planning

219 NAL Call No: 100 OR3OR
The greenhouse effect.
Gentle, T.
Corvallis, Or. : The Station; 1989.
Oregon's agricultural progress - Oregon Agricultural Experiment Station v. 35/36 (411): p. 22-26. ill; 1989.

Language: English

Descriptors: Air pollution; Carbon dioxide; Prediction; Models; Climatic change; Control methods

220 NAL Call No: QC879.8.W54
The greenhouse effect.
Wilson, David A.
Black Mountain, NC : Lorien House; 1989.
50 leaves : ill., maps ; 29 cm. LH-34. Includes bibliographical references (leaves 48-49).

Language: English

Descriptors: Greenhouse effect, Atmospheric; Atmospheric carbon dioxide; Atmospheric ozone; Reduction

221 NAL Call No: Z5158.N67
The greenhouse effect, a bibliography. (Greenhouse effect.)
Nordquist, Joan
Santa Cruz, CA, USA : Reference and Research Services; 1990.
60 p. ; 22 cm. (Contemporary social issues (Santa Cruz, Calif.) ; no. 18.).

Language: English

Descriptors: Greenhouse effect, Atmospheric

222 NAL Call No: KF26.E55 1987e
Greenhouse effect and global climate change hearings before the Committee on Energy and Natural Resources, United States Senate, One Hundredth Congress, first session ....
United States. Congress. Senate. Committee on Energy and Natural Resources
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O., 1988-; 1988-9999; Y 4.En 2:S.hrg.100-461. v. : ill., maps ; 24 cm. (S. hrg. ; 100-461). Distributed to some depository libraries in microfiche. "November 9 and 10, 1987", Pt. 1. "June 23, 1988", Pt. 2. Includes bibliographies.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global temperature changes; Fossil fuels, Environmental aspects, United States

223 NAL Call No: 500 AM322A
The greenhouse effect and nature reserves, global warming would diminish biological diversity by causing extinctions among reserve species.
Petersm R.L.; Darling, J.D.S.
Washington, D.C. : The Institute; 1985 Dec.
BioScience - American Institute of Biological Sciences v. 35 (11): p. 707-717. ill., maps; 1985 Dec. Includes references.

Language: English

Descriptors: Natural resources; Nature reserves; Air pollution; Climatic change; Adverse effects; Survival; Species; Diversity

224 NAL Call No: NBUS494.5 P75 I5 1990
The greenhouse effect and primary productivity in European agro-ecosystems proceedings of the International Workshop on Primary Productivity of European Agriculture and the Greenhouse Effect, Wageningen, the Netherlands, 5-10 April 1990.
Goudriaan, J.; Keulen, H. van; Laar, H. H. van
International Workshop on Primary Productivity of European Agriculture and the Greenhouse Effect 1990 : Wageningen, Netherlands.
Wageningen : Pudoc; 1990.
90 p. : ill. ; 24 cm. Includes bibliographical references.

Language: English

Descriptors: Agricultural productivity; Greenhouse effect, Atmospheric; Crops and climate; Climatic changes; Agricultural ecology

225 NAL Call No: NBUS455 G7
The greenhouse effect and UK agriculture papers and poster displays presented at a conference ... held at the Royal Society, London SW1 on July 14th 1989.
Bennett, R. M.
University of Reading, Centre for Agricultural Strategy
Reading : Centre for Agriculture Strategy, University of Reading; 1989.
144 p. : maps ; 21 cm. (CAS paper, 19).

Language: English

Descriptors: Greenhouse effect, Atmospheric; At-

mospheric carbon dioxide; Clinical changes; Agricultural ecology

226 **NAL Call No: SD390.7.G73G74**
The Greenhouse effect, climate change, and U.S. forests.
Shands, William E.; Hoffman, John S.
Conservation Foundation
Washington, D.C. : Conservation Foundation; 1987.
xiv, 304 p. : ill., maps ; 25 cm.

Language: English

Descriptors: Greenhouse effect, Atmospheric, United States; Forest meteorology, United States; Trees, United States, Climatic factors; Plants, Effect of carbon dioxide on, United States; Forest ecology, United States; Greenhouse effect, Atmospheric; Forest meteorology; Trees, Climatic factors; Plants, Effect of carbon dioxide on; Forest ecology

227 **NAL Call No: QC912.3.G73**
The Greenhouse effect, climatic change, and ecosystems.
Bolin, Bert,
International Council of Scientific Unions, Scientific Committee on Problems of the Environment
Chichester [West Sussex] ; New York : Published on behalf of the Scientific Committee on the Problems of the Environment of the International Council of Scientific Unions by Wiley; 1986.
xxxi, 541 p., 1 p. of plates : ill. (some col.) ; 24 cm. (SCOPE (Series) ; 29.). Includes bibliographies and index.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Climatic changes; Atmospheric carbon dioxide, Environmental aspects

228 **NAL Call No: QC879.8.R62**
The greenhouse effect global warming raises fundamental issues : environmental and energy study of conference special report.
Robock, Alan
Washington, D.C. : U.S. Congress; 1987.
8 leaves : ill. ; 28 cm. Caption title. September 1987.

Language: English

Descriptors: Greenhouse effect, Atmospheric; United States; Atmospheric carbon dioxide; United States; Atmospheric ozone; United States

229 **NAL Call No: QH545.A1E52**
The greenhouse effect: impacts of ultraviolet-B (UV-B) radiation, carbon dioxide (CO2), and ozone (O3) on vegetation.
Krupa, S.V.; Kickert, R.N.
Essex : Elsevier Applied Science; 1989.
Environmental pollution v. 61 (4): p. 263-393. maps; 1989. Includes references.

Language: English

Descriptors: Climatic change; Ozone; Carbon dioxide; Ultraviolet radiation; Vegetation; Plant damage; Air pollution; Stress response

230 **NAL Call No: HD9682.G73**
The Greenhouse effect investment implications and opportunities : proceedings of an Investor Forum held in New York City, October 4, 1989.
Cougan, Douglas G.
Investor Responsibility Research Center, World Resources Institute
Washington, D.C. : Investor Responsibility Research Center; 1990.
v, 158 p. : ill., maps ; 28 cm. Forum sponsors: Investor Responsibility Research Center, World Resources Institute.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Congresses; Global warming; Congresses; Climatic changes; Congresses

231 **NAL Call No: QC981.8.C5H4**
The greenhouse effect living in a warmer Australia.
Henderson-Sellers, A.; Blong, R. J.
Kensington, N.S.W. : New South Wales University Press; 1989.
211 p. : ill., maps ; 22 cm. Includes bibliographical references (p. [197]-198).

Language: English

Descriptors: Greenhouse effect, Atmospheric; Australia; Climatic changes; Australia; Atmospheric temperature; Australia; Solar radiation

232 **NAL Call No: HC79.E5G78**
The greenhouse effect negotiating targets.
Grubb, Michael
Royal Institute of International Affairs
London : Royal Institute of International Affairs; 1989.
viii, 56 p. : ill. ; 30 cm. (Energy and environmental

programme). Includes bibliographical references.

Language: English

Descriptors: Greenhouse effect, atmospheric; Environmental policy

233 NAL Call No: SB436.J6
The greenhouse effect: perceptions and misperceptions.
Cosgrove, T.J.
Urbana, Ill. : International Society of Arboriculture; 1989 Dec.
Journal of arboriculture v. 15 (12): p. 285-289; 1989 Dec. Includes references.

Language: English

Descriptors: World problems; Climate; Changes; Temperature; Problem analysis; Drought; Air pollution

234 NAL Call No: 292.9 C1282
The greenhouse effect: reality and potential consequences.
Rind, D.
Riverside, Calif. : The Center; 1990 May.
Report - California Water Resources Center, University of California (72): p. 69-72; 1990 May. Proceedings: Coping with Water Scarcity: The Role of Ground Water. Paper presented at the "Seventeenth Biennial Conference on Ground Water, September 25-26, 1989, San Diego, California. Includes references.

Language: English

Descriptors: U.S.A.; Climatic change; Water supply; Environmental impact

235 NAL Call No: QC912.3.G74
Greenhouse effect report.
Silver Spring, MD : Business Publishers; 1989-9999.
Greenhouse effect report. v. ; 28 cm; 1989-9999. Description based on: Vol. 2, no. 12 (Nov. 16, 1990); title from caption.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global warming

236 NAL Call No: 10 OU8
The greenhouse effect, meteorological mechanisms and models.
Hume, C.J.; Cattle, H.
Oxon : C.A.B. International; 1990.
Outlook on agriculture v. 19 (1): p. 17-23; 1990. Includes references.

Language: English

Descriptors: Climatic change; Air pollutants; Air temperature; Carbon dioxide; Clouds; Human activity; Meteorology; Methane; Nitrous oxide; Ozone; Simulation models

237 NAL Call No: TD420.A1E5
Greenhouse gases and global change: international collaboration.
Rosswall, T.
Washington, D.C. : American Chemical Society; 1991 Apr.
Environmental science & technology v. 25 (4): p. 567-573. maps; 1991 Apr. Includes references.

Language: English

Descriptors: Air pollution; Climatic change; Greenhouses; Gases; Carbon dioxide; Methane; Nitrous oxide; Ozone; International cooperation; Programs

238 NAL Call No: QC912.3.G735
Greenhouse planning for climate change.
Pearman, G. I.
Leiden ; New York : E.J. Brill; 1988.
xv, 752 p. : ill. ; 26 cm. Papers of a conference held at Monash University, Melbourne, in 1987. Includes bibliographies.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Australia; Congresses; Climatic changes; Australia; Congresses

239 NAL Call No: QC981.8.G56L97
The greenhouse trap what we're doing to the atmosphere and how we can slow global warming.
Lyman, Francesca
Boston : Beacon Press; 1990.
xvii, 190 p. : ill. ; 21 cm. (A World Resources Institute guide to the environment). Includes bibliographical references (p. 175-183) and index.

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric

240 NAL Call No: QC912.3.G737
Greenhouse warming abatement and adaptation.
Rosenberg, Norman J.,
Resources for the Future
Washington, D.C. : Resources for the Future; 1989.

xiii, 182 p. : ill. ; 28 cm. Proceedings of a workshop held in Washington, D.C. June 14-15, 1988; workshop sponsors, Resources for the Future ... [et al.]. Errata slip inserted. Includes bibliographical references.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Congresses; Climatic changes; Congresses

241 **NAL Call No: HD9000.1.F66**
Greenhouse warming and climate change, why should we care?
Crosson, P.
Guilford : Butterworths; 1989 May.
Food policy v. 14 (2): p. 107-118; 1989 May. Includes references.

Language: English

Descriptors: Climatic change; Atmosphere; Carbon dioxide; Temperatures; Trends; Agricultural policy

Abstract: Carbon dioxide levels in the earth's atmosphere will probably double by the middle of the next century, and this will lead to an increase in global average temperatures of between 1.5 degrees C and 5.5 degrees C. There would probably be shifts between regions in comparative agricultural advantage, but the ovcrall economic and environmental costs of world agricultural production would not necessarily rise. However, the gap between greenhouse gas emissions and the ability of the oceans and biosphere to absorb them is continuing to grow, and will eventually lead to further global warming with undoubtedly damaging consequences unless the trend is reversed. If coordinated international action is taken now, it is possible that the challenge can be met without sacrificing income growth.

242 **NAL Call No: QC912.3.G7374**
Greenhouse warming negotiating a global regime.
Benedick, Richard Elliot
Washington, D.C. : World Resources Institute; 1991.
98 p. : ill. ; 26 cm. January 1991. Includes bibliographical references.

Language: English

Descriptors: Greenhouse effect, Atmospheric; Global warming

243 **NAL Call No: QC879.8.H5**
High accuracy standards and reference methodology for carbon dioxide in air.
Zielinski, Walter L.
Washington, D.C. : U.S. Department of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division ; Gaithersburg, Md. : National Bureau of Standards, Center for Analytical Chemistry ; Springfield, Va. : Available from NTIS; 1986.
1 v. (various pagings) ; 28 cm. June 1986. Prepared under contract no. DE-A101-76PR06010. DOE/PR-06010-31. TR033. Bibliography: p. 74.

Language: English

Descriptors: Atmospheric carbon dioxide, Standards

244 **NAL Call No: GF55.M44**
High and dry Mediterranean climate in the twenty-first century.
Meith, Nikki
Oceans and Coastal Areas Programme Activity Centre, United Nations Environment Programme. mediterranean Co-ordinating Unit
Athens, Greece : Mediterranean Co-ordinating Unit of Programme Activity Centre for Oceans and Coastal Areas of the United Nations Environment Programme; 1989.
48 p. : ill. (some col.), maps ; 25 cm. Cover title. May 1989. Includes bibliographical references (p. 47).

Language: English

Descriptors: Man; Human ecology; Global warming; Greenhouse effect, Atmospheric

245 **NAL Call No: QC980.C55**
Historical evidence and climatic implications of a shift in the boreal forest tundra transition in central Canada.
Ball, T.F.
Dordrecht : D. Reidel Pub. Co; 1986 Apr.
Climatic change v. 8 (2): p. 121-134. maps; 1986 Apr. Includes references.

Language: English

Descriptors: Canada; Tundra; Boreal forests; Treelines and timberlines; Climatic factors; Climatic change; History; Plant ecology

246 **NAL Call No: 470 SCI2**
How fast can trees migrate?
Roberts, L.
Washington, D.C. : American Association for the Advancement of Science; 1989 Feb10.

Science v. 243 (4892): p. 735-737. ill., maps; 1989 Feb10.

Language: English

Descriptors: U.S.A.; Forest trees; Dispersion; Climatic change; Temperatures; Forest ecology

Abstract: If the climate models are correct, greenhouse warming will spell doom for many forests across the United States.

247 **NAL Call No: SD390.7.G73G74**
How forest products companies can respond to rising carbon dioxide and climate change.
Sandenburgh, R.; Taylor, C.; Hoffman, J.S.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 247-257; 1987. Includes references.

Language: English

Descriptors: Forest management; Forest products industries; Decision making; Development plans; Companies; Operational control; Climatic change; Carbon dioxide

248 **NAL Call No: TD171.U5**
How it might be: air pollution.
Durman, E.C.
Washington, D.C. : Office of Public Awareness; 1989 Jan.
EPA journal v. 15 (1): p. 23-24. ill; 1989 Jan.

Language: English

Descriptors: U.S.A.; Air pollution; Climatic change; Projections; Ozone; Acid rain; Temperatures; Environmental degradation; Standards

249 **NAL Call No: TD171.U5**
How it might be: water resources.
Smith, J.E.
Washington, D.C. : Office of Public Awareness; 1989 Jan.
EPA journal v. 15 (1): p. 19-20. ill; 1989 Jan.

Language: English

Descriptors: U.S.A.; Water resources; Air pollution; Projections; Climatic change; Water availability; Temperatures; Rain; Water supplies; Water allocation; Environmental impact reporting

250 **NAL Call No: 450 AN7**
How plants respond to climate change: migration rates, individualism and the consequences for plant communities.
Huntley, B.
London : Academic Press; 1991 Jun.
Annals of botany v. 67 (suppl.1): p. 15-22; 1991 Jun.
Literature review. Includes references.

Language: English

Descriptors: Climatic change; Adaptation; Plant communities; Paleoecology; Evolution; Ecosystems; Migration; Literature reviews

Abstract: The magnitude of climate changes forecast for the next century is comparable to the magnitude of warming during the last deglaciation. No climate change of similar magnitude has occurred since that event. The palaeoecological evidence of the response, especially of plants, to past climate change indicates that evolutionary adaptation has played no more than a minor role and that migration is the usual response of organisms to climate change. The individualism of response has important implications with respect to changes in the nature of vegetation and ecosystems. The maximum realized rates of migratory response by trees, although perhaps matching the maximum potential rates, are close to the maximum that it is believed can be achieved by such long-lived sessile organisms. The rate of climate change forecast for the future is 10-100 times faster than the rate of deglacial warming. Unless steps are taken to facilitate the migratory response of organisms to the forecast changes. then widespread extinction is likely. Artificial dispersal of trees and other organisms of limited dispersal and/or migratory capacity, the general extension of the legal protection currently afforded to some threatened organisms only within designated reserves, and the integration of wildlife habitat requirements and of wildlife corridors into human landscape utilization are all likely to be necessary. Stringent measures to limit the extent of future climate change by limiting emissions of greenhouse gases will also be necessary if the possibility of widespread and even catastrophic extinction is to be avoided.

251 **NAL Call No: 292.8 W295**
Hydrologic sensitivities of the Sacramento-San Joaquin River Basin, California, to global warming.
Lettenmaier, D.P.; Gan, T.Y.
Washington, D.C. : American Geophysical Union; 1990 Jan.
Water resources research v. 26 (1): p. 69-86. maps; 1990 Jan. Includes references.

Language: English

Descriptors: California; Hydrology; River basins; Catchment hydrology; Runoff; Flooding

252 **NAL Call No: S600.6.D4**
The impact of climate change from increased atmospheric carbon dioxide on American agriculture.
Decker, Wayne L.; Jones, Vernon K.; Achutuni, Rao
United States, Dept. of Energy
Washington, D.C. : Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division, [1986?]; 1986.
v, 100 p. : ill., maps ; 28 cm. May 1986. DOE/NBB-0077. Dist. Category UC-11. TR031. Contract No. W-7405-ENG-48. Bibliography: p. 92-100.

Language: English

Descriptors: Crops and climate, United States; Atmospheric carbon dioxide; Plants, Effect of carbon dioxide on; Agricultural pollution, United States

253 **NAL Call No: S600.7.C54146**
The Impact of climatic variations on agriculture.
Parry, M. L.; Carter, T. R.; Konijn, N. T.
International Institute for Applied Systems Analysis, United Nations Environment Programme
Dordrecht ; Boston : Kluwer Academic Publishers; 1988.
2 v. : ill., maps ; 25 cm. On v. 1 and 2 t.p.: The International Institute for Applied Systems Analysis, United Nations Environment Programme. "Funding was provided by UNEP, IIASA...", Pref. Includes bibliographies and indexes.

Language: English

Descriptors: Crops and climate; Climatic changes; Meteorology, Agricultural

254 **NAL Call No: QC980.C55**
The impact of climatic variations on British economic growth, 1856-1913.
Solomou, S.
Dordrecht : D. Reidel Pub. Co; 1986 Feb.
Climatic change v. 8 (1): p. 53-67; 1986 Feb. Includes references.

Language: English

Descriptors: United Kingdom; Climatic change; Agroclimatology; Climate; Economic growth; Primary sector; Agricultural production; History

255 **NAL Call No: QH543.P76**
The impact of CO2-induced climate change on crop-yields in England and Wales.
Palutikof, J.P.; Wigley, T.M.L.; Farmer, G.
Lisse : Swets & Zeitlinger; 1984.
Progress in biometeorology v. 3: p. 320-334. maps; 1984. Paper presented at the "Symposium on Interactions between Climate and Biosphere," March 21-23, 1983, Osnabruck, West Germany. Includes references.

Language: English

Descriptors: England; Wales; Crop yield; Climatic factors; Carbon dioxide; Atmosphere; Models

256 **NAL Call No: Q11.J68**
Impact of global warming and cooling on Midwestern agriculture.
Thompson, L.M.
Cedar Falls, Iowa : The Academy; 1990 Sep.
The Journal of the Iowa Academy of Science : JIAS v. 97 (3): p. 88-90; 1990 Sep. Includes references.

Language: English

Descriptors: Illinois; Iowa; Agroclimatology; Air temperature; Climatic change; Cooling; Crop yield; Drought; Zea mays

257 **NAL Call No: S541.5.A4M57**
The impact of increased air temperature on tundra plant communities.
Chapin, F.S. III
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 143-148; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Air temperature; Tundra; Carbon dioxide; Plant communities; Nutrient cycles

258 **NAL Call No: 281.8 C16**
The impacts of climate change on agriculture in Manitoba.
Mooney, S.; Arthur, L.M.
Ottawa : Canadian Agricultural Economics and Farm Management Society; 1990 Dec.
Canadian journal of agricultural economics; Revue Canadienne d'economie rurale v. 38 (4,pt.1): p. 685-694; 1990 Dec. Paper presented at a Workshop, July 23-25, 1990, Penticton, British Co-

lumbia. Includes referencces.

Language: English

Descriptors: Manitoba; Climatic change; Gross margins; Crop enterprises; Crop production; Economic impact; Carbon dioxide

259 NAL Call No: S600.2.C6 1985
Impacts of possible CO2-induced climate change on agriculture.
Jones, V.K.; Achutuni, R.; Decker, W.L.
Boston : The Society; 1985.
17th Conference on Agricultural and Forest Meteorology and seventh Conference on Biometeorology and Aerobiology, May 21-24, 1985, Scottsdale, Ariz. : [prcprint volume] / sponsored by the American Meteorological Society. p. 167-168; 1985. Includes references.

Language: English

Descriptors: U.S.A.; Agricultural meteorology; Climate; Carbon dioxide; Changes; Forecasting; Air pollution

260 NAL Call No: QH540.J6
Implications of a global climatic warming for agriculture: a review and appraisal.
Smit, B.; Ludlow, L.; Brklacich, M.
Madison, Wis. : Amcrican Society of Agronomy; 1988 Oct.
Journal of environmental quality v. 17 (4): p. 519-527; 1988 Oct. Includcs references.

Language: English

Descriptors: Climate; Climatic change; Agriculture; Carbon dioxide; Crop yield; Agricultural production

Abstract: Recently it has been recognized that changes in the chemical composition of the atmosphcre are likely to altcr the earth's climate, and that thesc alterations may have severe implications for agriculture and other economic activities. This has stimulated research into the possible consequences of altered climatic regimes on several attributes or components of agri-food systems. Current consensus suggests that a global climatic warming, induced by increased concentrations of CO2 and other "greenhouse" gases, is likely, and hcncc the possible implications of warmer climates for agriculture has received considerable attention. Several analytical procedures have been cmployed in thesc studies and it is timely to assess the characteristics and achievcments of these independent efforts. this paper classifies sod reviews studies that examine the implications of climatic warming for agriculture. Three approaches to assessment are recognized. Crop yield analysis identifies the effects of a specified change in climate on productivity levels for individual crops in particular locations. Spatial analysis examines the implications of climatic warming for the area and location of lands suitable for crop production. Agricultural systems analysis focuses on the relationships among components of agri-food systems. Much remains to be learned about the effects of climatic warming on agriculture. The use of existing information to develop a comprehensive analysis is hampered by differences in analytical approaches and in climatic change scenarios, and by the virtual absence of information on the possible implications of climatic change on agriculture in developing nations. Nevertheless, current evidence suggests that a warmer climate could create a more favorable environment for wheat (Triticum aestivum L.) and grain corn (Zea mays L.) in Canada, Northern Europe, and the USSR, and restrict opportunities in the USA.

261 NAL Call No: 1.90 C2OU8
Implications of global change for agriculture.
Rosenberg, N.J.
Washington, D.C. : The Department; 1990 Apr.
Outlook - Proceedings, Agricultural Outlook Conference, U.S. Department of Agriculture. p. 520-534. ill., maps; 1990 Apr.

Language: English

Descriptors: U.S.A.; Climatic change; Agricultural situation; Environmental pollution; World problems

262 NAL Call No: HD1750.W4
Implications of global climate change for western agriculture.
Adams, R.M.; McCarl, B.A.; Dudek, D.J.; Glyer, J.D.
Lincoln, Neb. : Western Agricultural Economics Association; 1988 Dec.
Western journal of agricultural economics v. 13 (2): p. 348-356; 1988 Dec. Includes references.

Language: English

Descriptors: Western states of U.S.A.; Agricultural production; Resource utilization; Climatic change; World problems; Economic impact; Irrigated farming; Carbon dioxide; Uncertainties

263 NAL Call No: KF27.I5474 1988d
Implications of global warming for natural resources oversight hearings before the Subcommittee on Water and Power Resources of the Committee on Interior and Insular Affairs, House of Representatives, One Hundredth Congress, second session ... hearings held September 27, 1988: Washington, DC; October 17, 1988: San Francisco, CA.
United States. Congress. House. Committee on Interior and Insular Affairs. Subcommittee on Water and Power Resources
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.In 8/14:100-58.
v, 668 p. : ill., maps ; 24 cm. Distributed to some depository libraries in microfiche. Shipping list no.: 89-395-P. Serial no. 100-58. Includes bibliographies.

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric; Climatic changes

264 NAL Call No: 382 SO12
Industry, agriculture and the atmosphere.
Essex : Elsevier Applied Science; 1990.
Journal of the science of food and agriculture v. 53 (3): p. 419-428. maps; 1990. Summaries of paper presented at a meeting of the Agriculture Group of the Society of Chemical Industry, January 23, 1990, London.

Language: English

Descriptors: Europe; Air pollution; Climatic change

265 NAL Call No: QC981.8.C5I46
The Influence of climate change and climatic variability on the hydrologic regime and water resources.
Solomon, S. I.; Beran, Max; Hogg, W. D.
International Union of Geodesy and Geophysics, General Assembly1987 :Vancouver, B.C.)
Wallingford, Oxfordshire, U.K. : International Association of Hydrological Sciences; 1987.
xiv, 640 p. : ill., maps ; 25 cm. (IAHS publication ; no. 168). Proceedings of an international symposium held during the XIXth General Assembly of the International Union of Geodesy and Geophysics at Vancouver, British Columbia, Canada, 9-22 August 1987. English and French. Includes bibliographical references.

Language: English; French

Descriptors: Climatic changes; Hydrology; Water-supply; Floods

266 NAL Call No: QC981.L5
Information on selected climate and climate-change issues.
Lins, Harry F.; Sundquist, E. T.; Ager, Thomas A. Geological Survey (U.S.)
Reston, Va. : U.S. Geological Survey; 1988.
iii, 26 p. : ill., maps ; 22 x 28 cm. (Open-file report (Geological Survey (U.S.)) ; 88-718.). Bibliography: p. 26.

Language: English

Descriptors: Weather; Climatic changes; Global temperature changes; Greenhouse effect, Atmospheric

267 NAL Call No: QC851.I57
Institutional directory, climate-related impacts network.
National Center for Atmospheric Research (U.S.), Environmental and Societal Impacts Group
Boulder, Colo. : Environment and Societal Impacts Group, National Center for Atmospheric Research; 1985-9999.
v. ; 28 cm. Description based on: 1989.

Language: English

Descriptors: Climatology; Climatic changes

268 NAL Call No: QH540.N3
Interaction between UV-B radiation and other stresses in plants.
Teramura, A.H.
Berlin, W. Ger. : Springer-Verlag; 1986.
N.A.T.O. A.S.I (Advanced Study Institute) series. Series G. Ecological sciences v. 8: p. 327-343; 1986. Paper presented at the "Workshop on The Impact of Solar Ultraviolet Radiation upon Terrestial Ecosystems: 1. Agricultural Crops," Sept 27-30, 1983, Windsheim, West Germany. Includes references.

Language: English

Descriptors: Ultraviolet radiation; Ozone; Reduction; Plant damage; Stress; Species; Cultivars; Water stress; Pigments; Biomass accumulation; Photosynthesis; Growth rate

269 NAL Call No: QK710.P55
The interaction of rising CO2 and temperatures with water use efficiency.
Eamus, D.

Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 843-852; 1991 Oct. Literature review. Includes references.

Language: English

Descriptors: Plants; Water use efficiency; Carbon dioxide enrichment; Transpiration; Air temperature; Climatic change; Crop yield; Literature reviews

270 NAL Call No: 450 P563
Investigations on stomata and stomatal clusters in Begonia: a possible stomatal indicator of tropical seasonal climate change.
Hoover, W.S.
Corvallis, Or. : Harold N. and Alma L. Moldenke; 1988 Sep.
Phytologia v. 65 (2): P. 89-96. maps; 1988 Sep. Includes references.

Language: English

Descriptors: Mexico; Begonia nelumbiifolia; Stomata; Leaf age; Climatic change; Size; Ecotones

271 NAL Call No: KF26.A35 1989d
Joint hearing on the potential impact of global warming on the Third World joint hearing before the Committee on Agriculture, Nutrition, and Forestry, and the Subcommittee on Foreign Operations, Export Financing, and Related Programs of the Committee on Appropriations, United States Senate, One Hundred First Congress, first session : special hearing.
United States. Congress. Senate. Committee on Agriculture, Nutrition, and Forestry; United States, Congress, Senate, Committee on Appropriations, Subcommittee on Foreign Operations, Export Financing, and Related Programs
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.Ag 8/3:S.hrg.101-303.
iv, 110 p. : ill. ; 24 cm. (S. hrg. ; 101-303). "Senate hearing", Cover. "Fiscal year 1990", Cover. Distributed to some depository libraries in microfiche. Includes bibliographical references.

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric; Climatic changes; Developing countries; Forest management; United States

272 NAL Call No: 410 EC7
Large-scale patterns of forest succession as determined by remote sensing.
Hall, F.G.; Botkin, D.B.; Strebel, D.E.; Woods, K.D.; Goetz, S.J.
Tempe, Ariz. : The Society; 1991 Apr.
Ecology : a publication of the Ecological Society of America v. 72 (2): p. 628-640. plates; 1991 Apr. Includes references.

Language: English

Descriptors: Minnesota; Forest ecology; Plant succession; Remote sensing; Climatic change; Ecosystems

273 NAL Call No: QH540.N3
Lead UV optical properties of Rumex patientia L. and Rumex obtusifolius L. in regard to a protective mechanism against solar UV-B radiation injury.
Robberecht, R.; Caldwell, M.M.
Berlin, W. Ger. : Springer-Verlag; 1986.
N.A.T.O. A.S.I (Advanced Study Institute) series. Series G. Ecological sciences v. 8: p. 251-259; 1986. Paper presented at the "Workshop on The Impact of Solar Ultraviolet Radiation upon Terrestial Ecosystems: 1. Agricultural Crops," Sept 27-30, 1983, Windsheim, West Germany. Includes references.

Language: English

Descriptors: Rumex patientia; Rumex obtusifolius; Leaves; Ultraviolet radiation; Plant damage; Radiation protection; Solar radiation; Epidermis; Pigments; Radiation reflectance

274 NAL Call No: TD420.A1E5
Living in a terrarium: reflections on the Second World Climate Conference.
Phillips, V.D.
Washington, D.C. : American Chemical Society; 1991 Apr.
Environmental science & technology v. 25 (4): p. 574-578. ill; 1991 Apr. Includes references.

Language: English

Descriptors: Climatic change; Air pollution; Greenhouses; Gases; Carbon dioxide; Nitrous oxide; Methane; Plants; Photosynthesis; Air quality; Plant breeding; Selection criteria; Problem solving

275 NAL Call No: S97.R4
Long-term climate change?
Woodman, J.N.
Raleigh, N.C. : North Carolina Agricultural Re-

search Service; 1987.
Research perspectives v. 6 (1): p. 17-18. ill; 1987.

Language: English

Descriptors: Climate; Weather patterns; Emission; Carbon dioxide; Vegetation

276 NAL Call No: QH543.P76
Long-term effects of an increased CO2 concentration level on terrestrial plants in model-ecosystems. I. Phytomass production and competition of Trifolium repens L. and Lolium perenne L.
Overdieck, D.; Bossemeyer, D.; Lieth, H.
Lisse : Swets & Zeitlinger; 1984.
Progress in biometeorology v. 3: p. 344-352; 1984. Paper presented at the "Symposium on Interactions between Climate and Biosphere," March 21-23, 1983, Osnabruck, West Germany. Includes references.

Language: English

Descriptors: Trifolium repens; Lolium perenne; Carbon dioxide; Concentration; Seed germination; Biomass accumulation; Competitive ability

277 NAL Call No: Q225.17
The making of a greenhouse policy.
Bromley, D.A.
Washington, D.C. : National Academy of Sciences; 1990.
Issues in science and technology v. 7 (1): p. 55-61; 1990.

Language: English

Descriptors: Climatic change; Research projects

278 NAL Call No: QC879.8.M38
Master index for the carbon dioxide research state-of-the-art report series.
Farrell, Michael P.
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, D.C. : U.S. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division ; Springfield, Va. : Available from National Technical Information Service, U.S. Dept. of Commerce; 1987.
vii, 253 p. ; 28 cm. DOE/ER-0316. An index to six State of the Art reports: Atmospheric carbon dioxide and the global carbon cycle; Direct effects of increasing carbon dioxide on vegetation; Detecting the climatic effects of increasing carbon dioxide; Projecting the climatic effects of increasing carbon dioxide; Characterization of information requirements for studies of CO2 effects; and, Glacier, ice sheets and sea level. March 1987. Bibliography: p. 59-62.

Language: English

Descriptors: Carbon dioxide, Environmental aspects, Indexes; Atmospheric carbon dioxide, Environmental aspects, Indexes

279 NAL Call No: 1.90 C2OU8
The meteorological causes of drought and long-term climate patterns.
Rodenhuis, D.R.
Washington, D.C. : The Department; 1989.
Outlook - Proceedings, Agricultural Outlook Conference, U.S. Department of Agriculture (65th): p. 530-533; 1989. Meeting held November 29-December 1, 1988, Washington, D.C.

Language: English

Descriptors: North America; Drought; Meteorological factors; Climatic change; Water resources; Trends

280 NAL Call No: QH344.G562
Methane emission from rice cultivation: geographic and seasonal distribution of cultivated areas and emissions.
Matthews, E.; Fung, I.; Lerner, J.
Washington, D.C. : American Geophysical Union; 1991 Mar.
Global biogeochemical cycles v. 5 (1): p. 3-24. ill; 1991 Mar. Includes references.

Language: English

Descriptors: Air quality; Climatic factors; Emission; Methane; Oryza sativa; Rice soils; Seasonality; Land use

281 NAL Call No: 292.8 J82
Methods for evaluating the regional hydrologic impacts of global climatic changes.
Gleick, P.H.
Amsterdam : Elsevier Scientific Publishers, B.V.; 1986 Nov15.
Journal of hydrology v. 88 (1/2): p. 97-116. maps; 1986 Nov15. Includes references.

Language: English

Descriptors: Climatic change; Regional surveys; Hydrological cycle; Air pollution; Carbon dioxide;

Environmental impact reporting; Evaluation; Models

282 **NAL Call No: QC981.8.G56T73**
Minding the carbon store weighing U.S. forestry strategies to slow global warming.
Trexler, Mark C.
World Resources Institute
Washington, D.C. : World Resources Institute; 1991.
x, 81 p. : ill. ; 26 cm. January 1991. Includes bibliographical references (p. 59-67).

Language: English

Descriptors: Global warming; Greenhouse effect, Atmospheric

283 **NAL Call No: Q225.I7**
The missing data on global climate change.
Hansen, J.
Washington, D.C. : National Academy of Sciences; 1990.
Issues in science and technology v. 7 (1): p. 62-69; 1990. Includes references.

Language: English

Descriptors: Climatic change; Research projects; Satellite surveys

284 **NAL Call No: QC988.A66G4**
Modeling effects of vegetation on climate.
Sellers, P.J.
New York : John Wiley for the United Nations University; 1987.
The Geophysiology of Amazonia : vegetation and climate interactions / Robert E. Dickinson, editor. p. 297-339. ill., maps; 1987. Includes references.

Language: English

Descriptors: Climate; Climatic change; Interactions; Vegetation; Mathematical models; Radiation balance; Solar radiation; Aerodynamics; Canopy

285 **NAL Call No: aQK751.U7 1988**
Models for analysis of vegetation responses to global environmental change.
Emanuel, W.R.; Prentice, I.C.; Smith, T.M.; Shugart, H.H. Jr; Solomon, A.M.
Broomall, PA : Northeastern Forest Experiment Station, [1989?]; 1989 Sep.
Air pollution effects on vegetation, including forest ecosystems : proceedings of the Second US-USSR Symposium / edited by Reginald D. Noble, Juri L. Martin, and Keith F. Jensen. p. 251-259; 1989 Sep. Papers presented at an International Conference, September 13-25, 1988, at Corvallis, Oregon; Raleigh, North Carolina; Gatlinburg, Tennessee. Includes references.

Language: English

Descriptors: Vegetation; Climatic change; Responses; Models

286 **NAL Call No: QK710.P55**
Modification of the response of photosynthetic productivity to rising temperature by atmospheric CO2 concentrations: has its importance been underestimated?
Long, S.P.
Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 729-739; 1991 Oct. Includes references.

Language: English

Descriptors: Plants; Carbon dioxide enrichment; Air temperature; Climatic change; Photosynthesis; Photorespiration; Carbon dioxide; Gas exchange; Leaves; Canopy; Mathematical models

287 **NAL Call No: QK710.P55**
Molecular responses of plants to an increased incidence of heat shock.
Howarth, C.J.
Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 831-841; 1991 Oct. Literature review. Includes references.

Language: English

Descriptors: Pennisetum Americanum; Sorghum bicolor; Heat shock; Heat shock proteins; Protein synthesis; Heat tolerance; Genotypes; Diurnal variation; Literature reviews; Climatic change

288 **NAL Call No: S541.5.A4M57**
A monitoring strategy to detect carbon dioxide-induced climatic changes in the polar regions.
Weller, G.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 23-30; 1984 Mar. Includes references.

Language: English

Descriptors: Polar regions; Carbon dioxide; Climatic change; Atmosphere; Oceanography; Climatology; Monitoring

289 NAL Call No: 470 SCI2
Monitoring the fate of the forests from space.
Booth, W.
Washington, D.C. : American Association for the Advancement of Science; 1989 Mar17.
Science v. 243 (4897): p. 1428-1429. maps; 1989 Mar17.

Language: English

Descriptors: Brazil; Forests; Remote sensing; Deforestation; Ecosystems; Atmospheric disturbances; Monitoring

Abstract: Remote sensing is a powerful tool for assessing rates of deforestation and answering questions about global warming and biodiversity; so why isn't anyone doing it?

290 NAL Call No: QH545.A1E52
Mycorrhizal mediation of plant response to atmospheric change: air quality concepts and research considerations.
Shafer, S.R.; Schoeneberger, M.M.
Essex : Elsevier Applied Science; 1991.
Environmental pollution v. 73 (3/4): p. 163-177; 1991. Special issue on "Plant Response to Atmospheric Change". Includes references.

Language: English

Descriptors: Plants; Stress; Mycorrhizas; Stress response; Climatic change; Atmosphere; Gases

291 NAL Call No: KF27.S3978 1987d
The National Climate Program Act and global climate change hearings before the Subcommittee on Natural Resources, Agriculture Reseacrch, and Environment and the Subcommittee on International Scientific Cooperation of the Committee on Science, Space, and Technology, U.S. House of Representatives, One Hundredth Congress, first session, July 22, 23, 29; September 30, 1987.
United States. Congress. House. Committee on Science, Space, and Technology. Subcommittee on Natural Resources, Agriculture Research, and Environment; United States, Congress, House, Committee on Science, Space, and Technology, Subcommittee on International Scientific Cooperation
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1988; Y 4.Sci 2:100/73.
iv, 760 p. : ill., maps ; 24 cm. Distributed to some depository libraries in microfiche. No. 73. Item 1025-A-1, 1025-A-2 (microfiche). Includes bibliographies.

Language: English

Descriptors: Global temperature changes; Climatic changes; Greenhouse effect, Atmospheric; Weather control, United States; Weather control, Law and legislation, United States

292 NAL Call No: KF26.F55 1988
National Energy Policy Act of 1988 and global warming hearings before the Committee on Energy and Natural Resources, United States Senate, One Hundredth Congress, second session, on S. 2667 ... August 11, September 19 and 20, 1988.
United States. Congress. Senate. Committee on Energy and Natural Resources
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.En 2:S.hrg.100-923.
iii, 543 p. : ill., maps ; 24 cm. (S. hrg. ; 100-923). Distributed to some depository libraries in microfiche. Includes bibliographies.

Language: English

Descriptors: Global temperature changes; Atmospheric carbon dioxide, United States; Environmental protection, United States

293 NAL Call No: KF26.C69 1989
National Global Change Research Act of 1989 hearing before the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred First Congress, first session, on S. 169 ... February 22, 1989.
United States. Congress. Senate. Committee on Commerce, Science, and Transportation
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.C 73/7:S.hrg.101-32.
iii, 185 p. : ill., maps ; 24 cm. (S. hrg. ; 101-32). Cover title. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Research; Greenhouse effect, Atmospheric; Research; Ozone layer depletion; Research; Global temperature changes; Research; Global warming; Research; Environmental law; United States

294 NAL Call No: QC981.8.C5N38
Natural areas facing climate change.
Malanson, George Patrick,
The Hague, The Netherlands : SPB Academic

Pub.; 1989.
92 p. : ill., maps ; 22 cm. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Climatology

295 NAL Call No: HM208.E5
Natural resources: greenhouse gases, climate change, and U.S. forest markets.
Regens, J.L.; Cubbage, F.W.; Hodges, D.G.
Washington, D.C. : Heldref Publications; 1989 May.
Environment v. 31 (4): p. 4-5, 41; 1989 May. Includes references.

Language: English

Descriptors: Great basin and pacific slope; South eastern states of U.S.A.; Pinus taeda; Pseudotsuga menziesii; Forest products industries; Forest management; Air pollution; Gases; Carbon dioxide; Climatic change

296 NAL Call No: QH543.P76
Net primary production deduced with the Hamburg model from climate change predictions with GCMs for elevated CO2 scenarios.
Lieth, H.
Lisse : Swets & Zeitlinger; 1984.
Progress in biometeorology v. 3: p. 335-343. maps; 1984. Paper presented at the "Symposium on Interactions between Climate and Biosphere," March 21-23, 1983, Osnabruck, West Germany. Includes references.

Language: English

Descriptors: Carbon dioxide; Atmosphere; Temperatures; Precipitation; Prediction; Models; Biological production

297 NAL Call No: S605.5.O74
New hardiness zone map.
Damsker, M.
Emmaus, Pa. : Rodale Press, Inc; 1990 Mar.
Organic gardening v. 37 (3): p. 85-84. maps; 1990 Mar.

Language: English

Descriptors: U.S.A.; Maps; Plants; Hardiness; Climatic change; Zoning; Usda

298 NAL Call No: 292.8 W295
A new method to determine regional evapotranspiration.
Magaritz, M.; Kaufman, A.; Paul, M.; Boaretto, E.; Hollos, G.
Washington, D.C. : American Geophysical Union; 1990 Aug.
Water resources research v. 26 (8): p. 1759-1762. maps; 1990 Aug. Includes references.

Language: English

Descriptors: Jordan; Evapotranspiration; Soil water recharge; Water reservoirs; Chlorides; Radionuclides; Precipitation; Climatic change; Hydrological cycle; Hydrological models; River basins

Abstract: A method is described whereby the chloride concentration and the ratio of 36Cl to total chloride of a given water body are compared with those of precipitation to determine the fraction of the original precipitation which was lost by evapotranspiration before it reached that water body. This method was applied to 11 water sources in the upper Jordan River basin, and the evapotranspirative loss was generally found to be in the range 40-90%. This method, which is much simpler than the other methods for determining regional evapotranspiration, will enable us to monitor the changes in the hydrological cycle which are expected to result from the greenhouse effect.

299 NAL Call No: S541.5.A4M57
Observed and predicted effects of climate change on Wolverine Glacier, Southern Alaska.
Mayo, L.R.; Trabant, D.C.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 114-123. maps; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Climatic change; Glaciology; Carbon dioxide; Hydrology; Air temperature

300 NAL Call No: QH543.P76
One-dimensional modelling of man's impacts on climate.
Tricot, C.
Lisse : Swets & Zeitlinger; 1984.
Progress in biometeorology v. 3: p. 91-100. ill; 1984. Paper presented at the "Symposium on Interactions between Climate and Biosphere," March 21-23, 1983, Osnabruck, West Germany. Includes references.

Language: English

Descriptors: Human activity; Climate; Models; Carbon dioxide; Concentration; Temperatures

301 NAL Call No: QC981.8.C5F42
Our changing planet the FY 1990 research plan : executive summary : the U.S. Global Change Research Program : a report. (Executive summary: the U.S. global change research program U.S. Global Change Research Program.)
Peck, Dallas L.
Federal Coordinating Council for Science, Engineering, and Technology. Committee on Earth Sciences
Washington, D.C. : The Committee; 1989.
ii, 43 p. : ill. ; 23 cm. Committee chairman: Dallas Peck. July 1989.

Language: English

Descriptors: Climatic changes; Research; United States; Climatic changes; Research; Government policy; United States; Earth; Research; United States; Earth; Research; Government policy; United States; Geodynamics; Research; United States; Geodynamics; Research; Government policy; United States; Earth sciences; United States; Earth sciences; Government policy; United States; Earth sciences; United States; Earth sciences; Government policy; United States

302 NAL Call No: QC981.8.C5F421
Our changing planet the FY 1990 research plan : the U.S. Global Change Research Program : a report. (U.S. Global Change Research Program.)
Peck, Dallas L.
Federal Coordinating Council for Science, Engineering, and Technology. Committee on Earth Sciences
Washington, D.C. : The Committee; 1989.
1 v. (various pagings) : ill. ; 28 cm. Committee chairman: Dallas Peck. July 1989.

Language: English

Descriptors: Climatic changes; Research; United States; Climatic changes; Research; Government policy; United States; Earth; Research; United States; Earth; Research; Government policy; United States; Geodynamics; Research; United States; Geodynamics; Research; Government policy; United States

303 NAL Call No: QC881.2.S8O97
Ozone depletion, greenhouse gases, and climate change proceedings of a joint symposium by the Board on Atmospheric Sciences and Climate and the Committee on Global Change, Commission on Physical Sciences, Mathematics, and Resources, National Research Council.
National Research Council (U.S.), Board on Atmospheric Sciences and Climate, National Research Council (U.S.), Committee on Global Change
Joint Symposium on Ozone Depletion, Greenhouse Gases, and Climate Change 1988 : National Academy of Sciences.
Washington, D.C. : National Academy Press; 1989.
xiv, 122 p. : ill. ; 23 cm. "Proceedings of the Joint Symposium on Ozone Depletion, Greenhouse Gases, and Climate Change, held at the National Academy of Sciences, March 23, 1988", P. xi. Includes bibliographies and index.

Language: English

Descriptors: Stratospheric ozone; Reduction; Congresses; Climatic changes; Congresses; Greenhouse effect, Atmospheric; Congresses

304 NAL Call No: RA569.8.O9
Ozone depletion health and environmental consequences.
Russell Jones, Robin; Wigley, T.
International Conference on the Health and Environmental Consequences of Stratospheric Ozone Depletion 1988 : Royal Institute of British Architects.
Chichester ; New York : Wiley ; New York, NY, USA : Distributed in the USA, Canada, and Japan by A.R. Liss; 1989.
xix, 280 p. : ill. ; 24 cm. "Proceedings of an International Conference on the Health and Environmental Consequences of Stratospheric Ozone Depletion, held at the Royal Institute of British Architects, London, on November 28-29, 1988", Pref. Includes bibliographical references.

Language: English

Descriptors: Ozone layer depletion; Health aspects; Congresses; Ozone layer depletion; Environmental aspects; Congresses; Greenhouse effect, Atmospheric; Congresses; Chlorofluorocarbons; Congresses; Global warming; Congresses

305 NAL Call No: KF26.E645 1986a
Ozone depletion, the greenhouse effect, and climate change hearings before the Subcommittee on Environmental Pollution of the Committee on Environment and Public Works, United States Senate, Ninety-ninth Congress, second session,

June 10 and 11, 1986.
United States. Congress. Senate. Committee on Environment and Public Works. Subcommittee on Environmental Pollution
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1986.
iv, 326 p. : ill., maps ; 24 cm. (S. hrg. ; 99-723). Distributed to some depository libraries in microfiche. Shipping list no.: 86-731-P. Includes bibliographies.

Language: English

Descriptors: Atmospheric ozone, Reduction, Government policy, United States; Greenhouse effect, Atmospheric, United States; Climatic changes, United States

306 NAL Call No: TD171.U5
Part of the problem and part of the answer.
Postel, S.
Washington, D.C. : Office of Public Awareness; 1989 Jan.
EPA journal v. 15 (1): p. 44-46. ill; 1989 Jan.

Language: English

Descriptors: U.S.A.; Air pollution; Problem solving; Forest policy; Afforestation; Carbon dioxide; Deforestation; Environmental impact reporting; Ecosystems; Climatic change

307 NAL Call No: QH301.P535
Photosynthesis and plant productivity, scaling to the biosphere.
Mooney, H.A.; Field, C.B.
New York, N.Y. : Alan R. Liss; 1989.
Plant biology v. 8: p. 19-44; 1989. In the series analytic: Photosynthesis / edited by W.R. Briggs. Proceedings of the C.S. French Symposium, July 17-23, 1988, Stanford, California. Literature review. Includes references.

Language: English

Descriptors: Photosynthesis; Biomass; Carbon cycle; Carbon dioxide; Ecosystems; Meteorology; Plant metabolism; Vegetation types; Literature reviews

308 NAL Call No: 472 N21
Photosynthesis seen from above.
Warrick, R.A.
Neptune, N.J. : Macmillan Journals; 1986 Jan16.
Nature v. 319 (6050): p. 181; 1986 Jan16. Includes 8 references.

Language: English

Descriptors: Climatic change; Vegetation; Remote sensing; Carbon dioxide; Atmosphere; Monitoring; Models

309 NAL Call No: QK710.P55
Physiology of inorganic C acquisition and implications for resource use efficiency by marine phytoplankton: relation to increased CO2 and temperature.
Raven, J.A.
Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 779-794; 1991 Oct. Literature review. Includes references.

Language: English

Descriptors: Phytoplankton; Carbon dioxide; Diffusion; Transport processes; Cell membranes; Photosynthesis; Ribulose-bisphosphate carboxylase; Enzyme activity; Carbon dioxide enrichment; Temperature; Sea water; Marine environment; Literature reviews

310 NAL Call No: SB191.W5L9 1974
Plans for wheat/climate-change research.
Sakamoto, C.
Houston, Tex. : Natl Aeronautics and Space Adm, Lyndon B. Johnson Space Center; 1975.
Proceedings of the 1974 Lyndon B. Johnson Space Center Wheat-Yield Conference. p. 2/1-2/4; 1975. (NASA TM ; X-58158).

Language: English

Descriptors: Planning of research; Models; Triticum; Crop yield; Climatic change; Cultivation; Areas; Agricultural meteorology

311 NAL Call No: SB123.3.C57
Plant genetic resources, a perspective.
Jackson, M.T.; Ford-Lloyd, B.V.
New York : Belhaven Press; 1990.
Climatic change and plant genetic resources / edited by M.T. Jackson, B.V. Ford-Lloyd, M.L. Parry. p. 1-17; 1990. Includes references.

Language: English

Descriptors: Climatic change; Air temperature; Carbon dioxide; Crops; Diversity; Genetic resources; Resource conservation

312 NAL Call No: QH545.A1E52
Plant response to atmospheric change: introduc-

tion.
Schoeneberger, M.M.; Shafer, S.R.
Essex : Elsevier Applied Science; 1991.
Environmental pollution v. 73 (3/4): p. 159-161; 1991. Special issue on "Plant Response to Atmospheric Change". Includes references.

Language: English

Descriptors: Mycorrhizas; Climatic change

313 **NAL Call No: QH540.J6**
Plant responses to rising carbon dioxide and potential interactions with air pollutants.
Allen, L.H. Jr
Madison, Wis. : American Society of Agronomy; 1990 Jan.
Journal of environmental quality v. 19 (1): p. 15-34; 1990 Jan. Literature review. Includes references.

Language: English

Descriptors: Plants; Plant damage; Stress response; Air pollution; Carbon dioxide; Climatic change; Photosynthesis; Transpiration; Leaf area; Biomass accumulation; Sulfur dioxide; Ozone

Abstract: As global population increases and industrialization expands, carbon dioxide (CO2) and toxic air pollutants can be expected to be injected into the atmosphere at increasing rates. This analysis reviews a wide range of direct plant responses to rising CO2, increasing levels of gaseous pollutants, and climate change, and to potential interactions among the factors. Although several environmental interactions on stomata and foliage temperatures are reviewed briefly, a comprehensive review of effects of potential climatic change on plants is not a major objective of this analysis. Research shows that elevated CO2 increases photosynthetic rates, leaf area, biomass, and yield. Elevated CO2 also reduces transpiration rate per unit leaf area, but not in proportion to reduction of stomatal conductance, because foliage temperature tends to rise. With increasing leaf area and foliage temperature, water use per unit land area is scarcely reduced by elevated CO2. Increases in photosynthetic water-use efficiency are caused primarily by increased photosynthesis rather than reduced transpiration. Gaseous pollutants (O3, SO2, NO2, H2S) affect plants adversely primarily by entry through the stomata. An example calculation showed that reduction in stomatal conductance by doubled CO2 could potentially reduce the effects of ambient O3 and SO2 by 15%. However, information on the interaction of CO2 and air pollutants is scanty. More research is needed on these interactions, because regional changes in air pollutants are occurring concurrently with global changes in CO2.

314 **NAL Call No: aS21.A8U5/ARS**
Point storm disaggregation, seasonal and regional effects.
Woolhiser, D.A.; Osborn, H.B.
Washington, D.C. : The Service; 1985.
Reprints - U.S. Department of Agriculture, Agricultural Research Service [76]: 16 p.; 1985. Includes references.

Language: English

Descriptors: Arizona; Climatic change; Rain; Regions; Runoff; Seasonal variation; Simulation models; Watershed management

315 **NAL Call No: QC981.8.C5N32**
The polar regions and climatic change.
National Research Council (U.S.). Committee on the Role of the Polar Regions in Climatic Change
Washington, D.C. : National Academy Press ; [available from Polar Research Board]; 1984.
xiv, 59 p. ; 23 cm. Bibliography: p. 54-59.

Language: English

Descriptors: Climatic changes; Polar regions

316 **NAL Call No: QC981.8.C5N3212**
The polar regions and climatic change appendix.
National Research Council (U.S.). Committee on the Role of the Polar Regions in Climatic Change
Washington, D.C. : National Academy Press ; [available from Polar Research Board]; 1984.
xi, 113 p. : ill. maps ; 23 cm. Cover title. Includes bibliographies.

Language: English

Descriptors: Polar regions; Climatic changes

317 **NAL Call No: KF26.E647 1989**
Policy options for stabilizing global climate hearing before the Subcommittee on Environmental Protection of the Committee on Environment and Public Works, United States Senate, One Hundred First Congress, first session, March 17, 1989.
United States. Congress. Senate. Committee on Environment and Public Works. Subcommittee on Environmental Protection
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S.

G.P.O.; 1989; Y 4.P 96/10:S.hrg.101-31.
iii, 69 p. : ill. ; 24 cm. (S. hrg. ; 101-31). Distributed to some depository libraries in microfiche.

Language: English

Descriptors: Global temperature changes; Greenhouse effect, Atmospheric; Climatic changes

318 NAL Call No: QC981.8.C5P6
Policy options of adaptation to climate change a study from Resources for the Future, Climate Resources Program.
Rosenberg, Norman J.,
Resources for the Future, Climate Resources Program
Washington, D.C. : Energy and Natural Resources Division, Resources for the Future; 1989.
45, 7 p. ; 28 cm. (Discussion paper (Resources for the Future) ; ENR 89-05.). March 1989. Chapter 8 of a report to the Governing Board of the United Nations Environmental Programme (UNEP). Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Government policy; Greenhouse effect, Atmospheric; Government policy; Environmental policy

319 NAL Call No: SD143.S64
Pollution and a changing climate, implications for world forests.
Woodman, J.N.
Bethesda, Md. : The Society; 1986.
Proceedings of the...Society of American Foresters National Convention. p. 29-33; 1986.

Language: English

Descriptors: Forests; Air pollution; Climate; Forest damage; Carbon dioxide; Temperatures

320 NAL Call No: 340.8 AM32
Possibilities of major climatic modification and their implications: northwest India, a case for study.
Bryson, R.A.; Baerreis, D.A.
Lancaster, Pa. : The Society :.; 1967 Mar.
Bulletin of the American Meteorological Socoiety v. 48 (3): p. 136-142. ill., maps; 1967 Mar. Includes references.

Language: English

Descriptors: India; Pakistan; Deserts; Dusts; Arid climate; Climatic change; Desertification; Archaeology

321 NAL Call No: S541.5.A4M57
Possible effects of a global warming on Arctic sea ice, precipitation, and carbon balance.
Kellogg, W.W.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 59-66. maps; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Carbon dioxide; Arctic regions; Climatic change; Environmental temperature; Arctic tundra

322 NAL Call No: 442.8 AN72
Possible impact of global warming on cabbage root fly (Delia radicum) activity in the UK.
Collier, R.H.; Finch, S.; Phelps, K.; Thompson, A.R.
Warwick : Association of Applied Biologists; 1991 Apr.
Annals of applied biology v. 118 (2): p. 261-271; 1991 Apr. Includes references.

Language: English

Descriptors: Uk; Delia radicum; Developmental stages; Diapause; Oviposition; Climatic change; Temperature; Simulation models

323 NAL Call No: 99.8 F767
Possible impacts of climatic warming on trees and forests in the United Kingdom: a review.
Cannell, M.G.R.; Grace, J.; Booth, A.
London : Oxford University Press; 1989.
Forestry : The journal of the Institute of Chartered Foresters v. 62 (4): p. 337-364. maps; 1989. Literature review. Includes references.

Language: English

Descriptors: United Kingdom; Forestry; Climatic change; Growth; Yields; Carbon dioxide; Forest soils; Soil temperature

324 NAL Call No: 281.8 C16
Potential adjustments to climatic change.
Arthur, L.M.
Ottawa : Canadian Agricultural Economics and Farm Management Society; 1990 Dec.
Canadian journal of agricultural economics; Revue Canadienne d'economie rurale v. 38 (4,pt.1): p. 711-716; 1990 Dec. Paper presented at a Workshop, July 23-25, 1990, Penticton, British Co-

lumbia. Includes references.

Language: English

Descriptors: Climatic change; Prevention; Environmental protection; Adaptability

325 NAL Call No: TD885.5.C3R5
Potential climatic impacts of increasing atmospheric CO2 with emphasis on water availability and hydrology in the United States report.
Rind, David; Lebedeff, Sergej
Goddard Institute for Space Studies, United States, Environmental Protection Agency, Office of Policy, Planning, and Evaluation, Strategic Studies Staff
Washington, D.C.? : U.S. Environmental Protection Agency, Strategic Studies Staff, Office of Policy Analysis, Office of Policy Planning and Evaluation; 1984; EP 1.2:C 61/2.
x, 96 leaves : ill., 3 maps ; 28 cm. April 1984. Cover title. EPA 230-04-84-006. DE85 901081. Bibliography: p. 94-96.

Language: English

Descriptors: Atmospheric carbon dioxide, United States, Measurement, Testing; Precipitation forecasting, United States

326 NAL Call No: QC980.C55
Potential CO2-induced climate effects on North American wheat-producing regions.
Rosenzweig, C.
Dordrecht : D. Reidel Pub. Co; 1985 Dec.
Climatic change v. 7 (4): p. 367-389. ill., maps; 1985 Dec. Includes references.

Language: English

Descriptors: North America; Carbon dioxide; Climatic change; Agroclimatic regions; Wheat; Crop production; Mapping; Simulation models

327 NAL Call No: S541.5.A4M57
The potential effects of carbon dioxide-induced climate changes in Alaska: conclusions and recommendations.
McBeath, J.H.; Weller, G.; Juday, G.P.; Osterkamp, T.E.; Neve, R.A.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 193-196; 1984 Mar.

Language: English

Descriptors: Alaska; Carbon dioxide; Climatic change; Projections; Climatic zones

328 NAL Call No: HD1750.W4
Potential effects of climate change on agriculture in the prairie region of Canada.
Arthur, L.M.; Abizadeh, F.
Lincoln, Neb. : Western Agricultural Economics Association; 1988 Dec.
Western journal of agricultural economics v. 13 (2): p. 216-224; 1988 Dec. Includes references.

Language: English

Descriptors: Canada; Agroclimatology; Carbon dioxide; Crop yield; Prairies; Climatic change; Simulation models

329 NAL Call No: NBULD3656 1991 K566
Potential effects of climate change on milk production and conception rate in dairy cattle in the United States and western Europe. (University of Nebraska, Lincoln thesis : Agronomy.)
Klinedinst, Peggy Lea
1991; 1991.
70 leaves ; 28 cm. Includes bibliographical references.

Language: English

330 NAL Call No: SD13.C35
Potential effects of climate change on stand development in the Pacific Northwest.
Dale, V.H.; Franklin, J.F.
Ottawa, Ont. : National Research Council of Canada; 1989 Dec.
Canadian journal of forest research; Journal canadien de recherche forestiere v. 19 (12): p. 1581-1590. maps; 1989 Dec. Includes references.

Language: English

Descriptors: Oregon; Washington; British Columbia; Climatic change; Stand development; Carbon dioxide; Simulation models; Ecosystems; Forest succession

331 NAL Call No: QK710.P55
Potential effects of elevated CO2 and changes in temperature on tropical plants.
Hogan, K.P.; Smith, A.P.; Ziska, L.H.
Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 763-778; 1991 Oct. Literature review. Includes references.

Language: English

Descriptors: Plants; Tropics; Carbon dioxide enrichment; Air temperature; Climatic change; Photosynthesis; Growth rate; Drought; Water use efficiency; Transpiration; Water stress; Literature reviews; Tropical zones

332 NAL Call No: QC981.8.C5P671
The Potential effects of global climate change on the United States [appendices].
Smith, Joel B.; Tirpak, Dennis A.
Washington, D.C. : Office of Policy, Planning and Evaluation, U.S. Environmental Protection Agency; 1989.
10 v. : ill., maps ; 28 cm. May 1989. "Policy, planning and evaluation (PM-221)", Cover. "EPA-230-05-89-051 - EPA-230-05-89-060, June 1989", Cover. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Climatic changes; Global warming; Greenhouse effect, Atmospheric

333 NAL Call No: S541.5.A4M57
Potential impact of a warmer climate on permafrost in Alaska.
Osterkamp, T.E.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 106-113. ill; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Permafrost; Carbon dioxide; Climatic change; Environment; Topography; Mathematical models

334 NAL Call No: SD390.7.G73G74
Potential impact of carbon dioxide-induced climate changes on management of Douglas-fir and western hemlock.
Woodman, J.N.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 277-283; 1987.

Language: English

Descriptors: U.S.A.; Tsuga heterophylla; Pseudotsuga menziesii; Climatic change; Carbon dioxide; Silvicultural systems; Forest management; Decision making

335 NAL Call No: KF26.A35 1988d
The potential impact of global warming on agriculture hearing before the Committee on Agriculture, Nutrition, and Forestry, United States Senate, One Hundredth Congress, second session ... December 1, 1988.
United States. Congress. Senate. Committee on Agriculture, Nutrition, and Forestry
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1989; Y 4.Ag 8/3:S.hrg.100-980.
iv, 108 p. : ill., maps ; 23 cm. (S. hrg. ; 100-980). Distributed to some despository libraries in microfiche. Bibliography: p. 33.

Language: English

Descriptors: Crops and climate, United States; Meteorology, Agricultural; Greenhouse effect, Atmospheric

336 NAL Call No: S541.5.A4M57
Potential impact on the arts in Alaska of carbon dioxide-induced climate change.
Woodward, K.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 178-183; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Landscape; Climatic change; Snow cover; Economic impact; Arts

337 NAL Call No: S601.A34
Potential impacts of a CO2-induced climate change using the GISS scenario on agriculture in Quebec, Canada.
Singh, B.; Stewart, R.B.
Amsterdam : Elsevier; 1991 May.
Agriculture, ecosystems and environment v. 35 (4): p. 327-347; 1991 May. Includes references.

Language: English

Descriptors: Quebec; Cereals; Oilseeds; Climatic change; Carbon dioxide; Dry matter; Biomass; Crop yield; Simulation models; Agricultural production; Agricultural regions

338 NAL Call No: 58.9 IN7
Potential impacts of climatic change in the UK.
Parry, M.
Silsoe : Institution of Agricultural Engineers; 1989.
The Agricultural engineer v. 44 (4): p. 124-125.

maps; 1989. Includes references.

Language: English

Descriptors: Uk; Climatic change; Crop production; Temperature; Rain; Location of production; Weeds; Diseases; Pests

339 **NAL Call No: 292.9 C1282**
Potential implications of global warming for California's water supply.
Dracup, J.A.; Kendall, D.R.
Riverside, Calif. : The Center; 1990 May.
Report - California Water Resources Center, University of California (72): p. 73-77; 1990 May. Proceedings: Coping with Water Scarcity: The Role of Ground Water. Paper presented at the "Seventeenth Biennial Conference on Ground Water, September 25-26, 1989, San Diego, California. Includes references.

Language: English

Descriptors: California; Water resources; Climatic change; Water supply

340 **NAL Call No: S541.5.A4M57**
Potential responses of permafrost to climatic warming.
Goodwin, C.W.; Brown, J.; Outcalt, S.I.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 92-105. maps; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Permafrost; Carbon dioxide; Climatic change; Simulation models; Computer software; Air temperature

341 **NAL Call No: SB123.3.C57**
Predicted climate changes under 'greenhouse-gas' warming.
Rowntree, P.R.
New York : Belhaven Press; 1990.
Climatic change and plant genetic resources / edited by M.T. Jackson, B.V. Ford-Lloyd, M.L. Parry. p. 18-33; 1990. Includes references.

Language: English

Descriptors: Climatic change; Air quality; Air temperature; Carbon dioxide; Gases; Soil water; Weather data

342 **NAL Call No: SD390.7.G73G74**
Predicting regional climate change: improving the models.
Rind, D.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 77-90. maps; 1987. Includes references.

Language: English

Descriptors: Climatic change; Models; Prediction; Atmosphere; Carbon dioxide; Thermal radiation; World problems

343 **NAL Call No: QH541.15.M3E25**
Predicting the response of plants to increasing carbon dioxide: a critique of plant growth models.
Reynolds, J.F.; Acock, B.
Amsterdam : Elsevier; 1985 Sep.
Ecological modelling v. 29 (1/4): p. 107-129. ill; 1985 Sep. Includes references.

Language: English

Descriptors: Plants; Carbon dioxide; Growth; Vegetation; Models; Evaluation criteria

344 **NAL Call No: GB746.W33**
Predictive estimation of natural groundwater resources in the near future.
Kovalevskii, V.S.; Maksimova, N.G.
New York, N.Y. : Consultants Bureau; 1989 Jan.
Water resources v. 15 (2): p. 133-139. maps; 1989 Jan. Translated from Vodnye Resursy, v. 15 (2), March-April, 1988, p. 41-49. (GB746.V55). Includes references.

Language: English; Russian

Descriptors: U.S.S.R.in europe; Groundwater; Water resources; Prediction; Estimation; Climatic change; Runoff water; Precipitation; Air temperature; Groundwater recharge

345 **NAL Call No: 500 AM322A**
Preparing for climate change.
Tangley, L.
Washington, D.C. : The Institute; 1988.
BioScience - American Institute of Biological Sciences v. 38 (1): p. 14-18. ill; 1988.

Language: English

Descriptors: Climatic change; Carbon dioxide; Drought; Adaptation; Agriculture; Forestry; Fisheries

346 NAL Call No: QC981.8.C5N67 1987
Preparing for climate change proceedings of the First North American Conference on Preparing for Climate Change, a cooperative approach : October 27-29, 1987, Washington, D.C.
Climate Institute (Washington, D.C.)
North American Conference on Preparing for Climate Change 1st : 1987 : Washington, D.C.
Rockville, Md. : Government Institutes; 1988.
xiv, 516 p. : ill. ; 28 cm. "April 1988", T.p. verso. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Congresses; Climatic changes; North America; Congresses

347 NAL Call No: Q225.17
Preventing climate change.
Schneider, C.
Washington, D.C. : National Academy of Sciences; 1989.
Issues in science and technology v. 5 (4): p. 55-62; 1989. Includes references.

Language: English

Descriptors: Climatic change; Air pollutants; Carbon dioxide; Methane; Deforestation; Afforestation; Forest influences

348 NAL Call No: QC981.8.C5R67
A primer on climatic change mechanisms trends and projections.
Rosenberg, Norman J.,
Resources for the Future, Renewable Resources Division
Washington, D.C. : Renewable Resources Division, Resources for the Future; 1986.
67, 7 p. ; 28 cm. (Discussion paper series (Resources for the future. Renewable Resources Division) ; no. RR86-04.). "August 1986. Includes bibliographical references (p. 57-66).

Language: English

Descriptors: Climatic changes

349 NAL Call No: QC879.8.C372 1980
Proceedings of the Carbon Dioxide and Climate Research Program Conference, Washington, DC, April 24-25, 1980.
Schmitt, Lois E.
United States, Dept. of Energy, Office of Health and Environmental Research, Oak Ridge Associated Universities, Institute for Energy Analysis
Carbon Dioxide and Climate Research Program Conference 1980 : Washington, D.C.
Washington, D.C. : U.S. Dept. of Energy, Assistant Secretary for Environment, Office of Health and Environmental Research ; Springfield, Va. : Available from National Technical Information Service; 1980; E 1.10-8004110.
xviii, 287 p. : ill. ; 28 cm. (Carbon Dioxide Effects Research and Assessment Program ; 011). December 1980. Contract no. DE-AC05-760R00033. CONF-8004110. Includes bibliographies.

Language: English

Descriptors: Atmospheric carbon dioxide, Environmental aspects, Congresses; Climatology, Congresses

350 NAL Call No: QC879.8.I57 1979
Proceedings of the International Meeting on Stable Isotopes in Tree-Ring Research New Paltz, N.Y., May 22-25, 1979.
Jacoby, Gordon
Lamont-Doherty Geological Observatory, United States, Dept. of Energy, Office of the Assistant Secretary for Environment, United States, Dept. of Energy, Office of Health and Environmental Research
International Meeting on Stable Isotopes in Tree-Ring Research 1979 : New Paltz, N.Y.
Washington, D.C. : U.S. Dept. of Energy, Assistant Secretary for Environment, Office of Health and Environmental Research ; Springfield, Va. : Available from National Technical Information Service; 1980; E 1.10-790518.
iii, 150 p. : ill. ; 28 cm. (Carbon Dioxide Effects Research and Assessment Program ; 012). December 1980. CONF-7905180. "CONF-790518", Cover. Includes bibliographies.

Language: English

Descriptors: Atmospheric carbon dioxide, Environmental aspects, Congresses; Climatology, Congresses; Isotopes

351 NAL Call No: QC981.8.C5S95 1987
Proceedings of the Symposium on Climate Change in the Southern United States future impacts and present policy issues : May 28-29, 1987, New Orleans, Louisiana.
Meo, Mark
University of Oklahoma, Science and Public Policy Program, United States, Environmental Protection Agency, Office of Policy, Planning, and Evaluation
Symposium on Climate Change in the Southern

United States 1987 : New Orleans, La.
S.l. : s.n.; 1987.
vi, 608 p. : ill. ; 28 cm. November 1987. "Addendum to list of attendees" inserted. "Conducted by the Science and Public Policy Program, University of Oklahoma; sponsored by the U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation.", Cover. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Southern States; Congresses; Environmenal policy; Southern States; Congresses

352 NAL Call No: QC879.8.P76
Projecting the climatic effects of increasing carbon dioxide.
MacCracken, Michael C.; Luther, F. M.
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, D.C. : U.S. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division; 1985.
xxv, 381 p. : ill. ; 28 cm. DOE/ER-0237. December 1985. Dist. Category UC-11. Includes bibliographies and indexes.

Language: English

Descriptors: Atmospheric carbon dioxide; Mathematical models; Climatic changes; Mathematical models

353 NAL Call No: QC879.8.M37
The prospect of solving the CO2 problem through global reforestation.
Marland, Gregg
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, D.C. : U.S. Dept. of Energy ; Springfield. Va. : Available from the National Technical Information Service, U.S. Dept. of Commerce; 1988.
ix, 66 p. : ill. ; 28 cm. "Prepared for United States Department of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division under Contract No. DE-AC05-76OR00033, DE-AC05-84OR21400", Cover. February 1988. TRO39. Under contract no. DE-AC05-76OR00033, DE-AC05-OR21400. Bibliography: p. 60-66.

Language: English

Descriptors: Atmospheric carbon dioxide; Reforestation

354 NAL Call No: QC981.8.C5P7
Prospects for future climate a special US/USSR report on climate and climate change.
MacCracken, Michael C.
Chelsea, Mich. : Lewis Publishers; 1990.
xiii, 270 p. : ill. ; 24 cm. Prepared under the auspices of the US/USSR agreement on protection of the environment. Includes bibliographical references (p. 235-267).

Language: English

Descriptors: Climatic changes; Climatology

355 NAL Call No: TD885.5.O85C52
Protecting the ozone layer what you can do : a citizens' guide to reducing the use of ozone depleting chemicals.
Clark, Sarah L.
Environmental Information Exchange
New York, NY (257 Park Avenue South, New York, NY 10010) : Environmental Information Exchange, Environmental Defense Fund; 1988.
33 p. : ill. ; 21 cm. Bibliography: p. 30-31.

Language: English

Descriptors: Ozone layer depletion; Atmospheric ozone; Reduction; Environmental protection; United States; Citizen participation

356 NAL Call No: QK477.2.A6I5 1986
Radiodensitometric tree-ring analysis along altitudinal gradients: some alternative procedures for detecting site, climatic, and potential CO2 effects on tree growth.
Kienast, F.
Washington, DC : U.S. Department of Energy, Office of Energy Research; 1987 Apr.
Proceedings of the International Symposium on Ecological Aspects of Tree-Ring Analysis / compiled by G.C. Jacoby, J.W. Hornbeck. p. 452-462; 1987 Apr. Includes references.

Language: English

Descriptors: Switzerland; Colorado; Cyprus; Coniferae; Forest trees; Growth rings; Growth; Environmental factors; Site factors; Carbon dioxide; Altitudinal zonation

357 NAL Call No: QC981.8.C5U5
Recommendations from an interdisciplinary forum on data management for global change, Baltimore, Maryland, November 2-4, 1988. (Data

management for global change.)
Unninayar, Sushil; Ruttenberg, Stan
United States, Interagency Working Group on Data Management for Global Change, University Corporation for Atmospheric Research, Office for Interdisciplinary Earth Studies
Boulder, CO : Office for Interdisciplinary Earth Studies, University Corporation for Atmospheric Research; 1990.
[vii], 75 p. : ill. ; 28 cm. (Report OIES ; 5). Sponsored by the Interagency Working Group on Data Management for Global Change of the Committee on Earth Sciences. March 1990.

Language: English

Descriptors: Climatic changes

358 NAL Call No: 472 N21
Reconstruction of tree-line vegetation response to long-term climate change.
Payette, S.; Filion, L.; Delwaide, A.; Begin, C.
London : Macmillan Magazines Ltd; 1989 Oct.
Nature v. (341) (6241): p. 429-432; 1989 Oct. Includes references.

Language: English

Descriptors: Canada; Picea mariana; Betula glandulosa; Climatic change; Carbon dioxide; High altitude

Abstract: Knowledge of the vegetation response to climate change is necessary to assess and predict realistic ecosystem development in the antipicated, CO2-induced warmer world, particularly at high latitudes where greater warming is expected. Reconstruction of vegetation development over the past 1,000 years may be helpful in this respect, because this period was characterized by contrasting climatic conditions. Here we report the reconstruction of wind-exposed, tree-line vegetation associated with long-term climate change in northern Canada, using tree-ring and growth-form analyses of spruce subfossils. Three major types of growth form within the exposed, but stable, lichen-spruce community successively predominated in response to climate forcing: high krummholz (dwarf spruce, less than 2-m high) with scarce small (greater than 2-m high) trees (AD 1305-1435, cool period), trees (greater than 2-3 m high) and high krummholz (AD 1435-1570, warm period) and low krummholz (less than or about 50 cm) (little ice age to present: AD 1570 onwards, cold period and present climate, respectively). Whereas the expansion of a marginal lichen-spruce woodland climaxed during the late Middle Ages (AD 1435-1570), present development of a low-krummholz vegetation at these sites seems to be out of phase with the twentieth century warming. This suggests that ecosystem recovery to global warming is not straightforward, depending on the nature of vegetation structure present at the time climate change occurred. The implications of such ecosystem resilience for the detection and monitoring of the expected CO2-induced warming is discussed, particularly for the climate-sensitive arctic and subarctic regions.

359 NAL Call No: GB611.D47
Reflections on desertification 1977-1987: problems and prospects.
Rapp, A.
Nairobi, Kenya : United Nations Environment Programme; 1987.
Desertification control bulletin (15): p. 27-33. maps; 1987. Includes references.

Language: English

Descriptors: Africa; Desertification; Climatology; Land use; Climatic change; Dry farming; Arid zones; International cooperation

360 NAL Call No: 500 AM322A
Regional analysis of the central Great Plains.
Burke, I.C.; Kittel, T.G.F.; Lauenroth, W.K.; Snook, P.; Yonker, C.M.; Parton, W.J.
Washington, D.C. : The Institute; 1991 Nov.
BioScience - American Institute of Biological Sciences v. 41 (10): p. 685-692; 1991 Nov. Includes references.

Language: English

Descriptors: U.S.A.; Land management; Plains; Biomass production; Carbon cycle; Climatic change; Ecosystems; Environmental factors; Simulation models; Site factors

361 NAL Call No: QC981.8.C5G76
Regional intercomparisons of general circulation model predictions and historical climate data.
Grotch, Stanley L.
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, DC : U.S. Dept. of Energy ; Springfield, Va. : available from N.T.I.S.; 1988.
xviii, 291 p. : ill. ; 28 cm. (DOE/NBB ; 0084). TR041. April 1988. Prepared under contract no. W-7405-ENG-48. Bibliography: p. 257-258.

Language: English

Descriptors: Atmospheric carbon dioxide; Environmental aspects; Climatic changes; Mathematical models; Atmospheric circulation; Mathematical models; Precipitation (Meteorology); Air; Thermal properties

362 NAL Call No: 472 N21
Relationship between atmospheric CO2 variations and a satellite-derived vegetation index.
Tucker, C.J.; Fung, I.Y.; Keeling, C.D.; Gammon, R.H.
Neptune, N.J. : Macmillan Journals; 1986 Jan16.
Nature v. 319 (6050): p. 195-199. ill; 1986 Jan16. Includes 37 references.

Language: English

Descriptors: Carbon dioxide; Atmosphere; Vegetation; Remote sensing; Satellites; Bioclimatic indexes

363 NAL Call No: 99.8 F762
Releaf for global warming.
Sampson, R.N.
Washington, D.C. : American Forestry Association; 1988 Nov.
American forests v. 94 (11/12): p. 9-14. ill; 1988 Nov.

Language: English

Descriptors: Afforestation; Organizations; Environmental degradation; Pollution; Climatic factors; Deforestation; Development projects

364 NAL Call No: QC981.8.C5I58 1985
Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts, Villach, Austria, 9-15 October 1985.
World Climate Programme, International Council of Scientific Unions, United Nations Environment Programme, World Meteorological Organization
International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts 1985 : Villach, Austria.
Paris : International Council of Scientific Unions; 1986.
78 p. : ill. ; 30 cm. (WMO (Series) ; 661.). At head of title: World Climate Programme. Sponsored by the International Council of Scientific Unions, the United Nations Environment Programme, and the World Meteorological Organization. Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Congresses; Environmental impact analysis; Congresses; Atmospheric carbon dioxide; Environmental aspects; Congresses; Greenhouse gases; Congresses; Greenhouse effect, Atmospheric; Congresses

365 NAL Call No: 290.9 AM32T
Response of crop yield to predicted changes in climate and atmospheric CO2 using simulation.
Curry, R.B.; Peart, R.M.; Jones, J.W.; Boote, K.J.; Allen, L.H. Jr
St. Joseph, Mich. : American Society of Agricultural Engineers; 1990 Jul.
Transactions of the ASAE v. 33 (4): p. 1383-1390; 1990 Jul. Includes references.

Language: English

Descriptors: Southeastern states of U.S.A.; Glycine max; Crop yield; Climatic change; Atmosphere; Carbon dioxide; Simulation models; Irrigation

Abstract: Soybean growth and yield for 19 locations in southeastern U.S.A. were simulated for 30 years (1951-80) of climate data. Three different climate change scenarios, with and without supplemental irrigation, were used with the SOYGRO crop model. The three climate scenarios were standard historic data and two scenarios based on changes predicted by two general circulation models (GCM) for a doubling of atmospheric carbon dioxide. Results were analyzed for four different conditions; normal weather, doubled CO2 alone, climate change alone, and the combined effect of climate change and doubled CO2. Results indicate 1) yields vary widely with climate scenario; 2) increased water use and irrigation need for the combined case of doubled CO2 and climate change; and 3) simulation is a useful tool for this type of study.

366 NAL Call No: 472 N21
Response of northern forests to CO2-induced climate change.
Pastor, J.; Post, W.M.
London : Macmillan Magazines Ltd; 1988 Jul07.
Nature 334 (6177): p. 55-58; 1988 Jul07. Includes references.

Language: English

Descriptors: North America; Forest influences; Forest trees; Growth; Inhibition; Yield losses; Plant density; Forest ecology; Climatic change;

Carbon dioxide

367 NAL Call No: QH543.P76
Response of the North American corn belt to climatic warming.
Blasing, T.J.; Solomon, A.M.
Lisse : Swets & Zeitlinger; 1984.
Progress in biometeorology v. 3: p. 311-321. maps; 1984. Paper presented at the "Symposium on Interactions between Climate and Biosphere," March 21-23, 1983, Osnabruck, West Germany. Includes references.

Language: English

Descriptors: North America; Agricultural regions; Zea mays; Climate; Temperature; Atmosphere; Carbon dioxide; Crop production

368 NAL Call No: QC981.8.C5R47
Response of the North American corn belt to climatic warming,CO2.
United States, Dept. of Energy, Office of Energy Research, United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, D.C. : prepared for U.S. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division ; Springfield, Va. : available from NTIS; 1983.
ii, 27 p. : ill., maps ; 28 cm. Cover title. August 1983. DOE/NBB-0040. TR006. Bibliography: p. 25-27.

Language: English

Descriptors: Atmospheric carbon dioxide; Climatic changes; Corn

369 NAL Call No: SD387.E58R4
Response of unmanaged forests to CO2-induced climate change available information, initial tests, and data requirements.
Solomon, Allen M.
United States, Dept. of Energy, Office of Basic Energy Sciences, Carbon Dioxide Research Division
Washington, D.C. : The Division ; Springfield, Va. : Available from NTIS; 1984.
xiii, 93 p. : ill., maps ; 28 cm. April 1984. Contract no. W-7405-ENG-26. TR009. DOE/NBB-0053. Dist. Category UC-11. Bibliography: p. 77-93.

Language: English

Descriptors: Forests and forestry, Environmental aspects, North America; Forest microclimatology, North America; Carbon dioxide

370 NAL Call No: QH540.F85
Response to CO2 enrichment in 27 herbaceous species.
Hunt, R.; Hand, D.W.; Hannah, M.A.; Neal, A.M.
Oxford, U.K. : British Ecological Society; 1991.
Functional ecology v. 5 (3): p. 410-421; 1991. Includes references.

Language: English

Descriptors: Plants; Helianthus annuus; Zea mays; Carbon dioxide enrichment; Biomass production; Dry matter accumulation; Adaptability; Climatic change; Plant ecology; Plant competition; Competitive ability; Equations

371 NAL Call No: 410 EC7
The responses of a forest model to serial correlations of global warming.
Cohen, Y.; Pastor, J.
Tempe, Ariz. : The Society; 1991 Jun.
Ecology : a publication of the Ecological Society of America v. 72 (3): p. 1161-1165; 1991 Jun. Includes references.

Language: English

Descriptors: Forest ecology; Forest trees; Air temperature; Carbon dioxide; Climatic change; Ecosystems; Nitrogen; Nutrient availability; Simulation models

372 NAL Call No: Q225.I7
Rethinking the economics of global warming.
Miller, A.; Mintzer, I.; Brown, P.G.
Washington, D.C. : National Academy of Sciences; 1990.
Issues in science and technology v. 7 (1): p. 70-73; 1990. Includes references.

Language: English

Descriptors: Climatic change; Economics

373 NAL Call No: S600.7.E93N3 1985
Rising atmospheric CO2 evapotranspiration.
Allen, L.H. Jr; Jones, P.; Jones, J.W.
St. Joseph, Mich. : American Society of Agricultural Engineers; 1985.
Advances in Evapotranspiration : proceedings of the National Conference on Advances in Evapotranspiration, December 16-17, 1985, Hyatt Regency Chicago, Chicago, Illinois. p. 13-25; 1985. (ASAE publication ; 14-85). Literature review. Includes 41 references.

Language: English

Descriptors: Evapotranspiration; Carbon dioxide; Atmosphere; Photosynthesis; Leaves; Transpiration; Water use efficiency; Mathematical models

374 NAL Call No: SD390.7.G73G74
Rising carbon dioxide, climate change, and forest management: an overview.
Sandenburgh, R.; Taylor, C.; Hoffman, J.S.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 113-121; 1987. Includes references.

Language: English

Descriptors: Forest trees; Photosynthesis; Productivity; Climatic change; Carbon dioxide; Growth rate; Thermal radiation; Forest management

375 NAL Call No: QK710.P55
Rising CO2 levels and their potential significance for carbon flow in photosynthetic cells.
Stitt, M.
Oxford : Blackwell Scientific Publications; 1991 Oct.
Plant, cell and environment v. 14 (8): p. 741-762; 1991 Oct. Literature review. Includes references.

Language: English

Descriptors: Plants; Carbon dioxide enrichment; Photosynthesis; Ribulose-bisphosphate carboxylase; Enzyme activity; Sucrose; Carbohydrate metabolism; Acclimatization; Source sink relations; Literature reviews

376 NAL Call No: S541.5.A4M57
The rising level of atmospheric carbon dioxide: an agricultural perspective.
Wittwer, S.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 163-169. ill; 1984 Mar. Includes references.

Language: English

Descriptors: Carbon dioxide; Climatic change; Agroclimatology; Photosynthesis; Plant competition

377 NAL Call No: QC981.8.G56E34
The rising tide global warming and world sea levels.
Edgerton, Lynne T.
Washington, D.C. : Island Press; 1991.
xviii, 140 p. : ill. ; 24 cm. Includes bibliographical references (p. 122-128) and index.

Language: English

Descriptors: Global warming; Climatic changes; Sea level; Science and state; Science and state

378 NAL Call No: SD13.C35
The role of climate on present and past vitality of silver fir forests in the Vosges mountains of north-eastern France.
Becker, M.
Ottawa, Ont. : National Research Council of Canada; 1989 Sep.
Canadian journal of forest research; Journal canadien de recherche forestiere v. 19 (9): p. 1110-1117; 1989 Sep. Includes references.

Language: English

Descriptors: France; Abies alba; Dendroclimatology; Growth rings; Climatic factors; Carbon dioxide; Air pollution

379 NAL Call No: 450 AN7
The role of ozone in global change.
Ashmore, M.R.; Bell, J.N.B.
London : Academic Press; 1991 Jun.
Annals of botany v. 67 (suppl.1): p. 39-48; 1991 Jun. Literature review. Includes references.

Language: English

Descriptors: Climatic change; Air pollution; Ozone; Forest trees; Crops; Phytotoxicity; Literature reviews

Abstract: Over recent years convincing evidence has emerged of both a decrease in stratospheric ozone concentrations and an increase in tropospheric ozone concentration These trends can be attributed primarily to increased global emissions of chlorofluorocarbons and of nitrogen oxides, respectively. Ozone plays an important role in the earth's atmosphere and changes in its concentration are of concern for several reasons: increased penetration of ultraviolet (UV) radiation, a contribution to global warming, perturbations in atmospheric chemistry, and direct toxic effects on the terrestrial biosphere. Concern over the direct toxic effects arises both from the expansion of the global area affected by regional episodes of elevated ozone concentrations, and an increased concentration in the background troposphere. Tropospheric

ozone concentrations will continue to rise, in the absence of effective emission control measures, because of increased energy consumption and motor vehicle use, and any increase in concentrations will have detrimental effects on sensitive terrestrial ecosystems. Ozone should be considered as a component of global change, and priority be given to understanding its interaction with other, more important, factors such as CO2 concentration, water availability and temperature. Other important interactions may arise from the fact that ozone alters the performance of herbivorous insect pests and of plant pathogens, which will themselves be influenced by climate change.

380 NAL Call No: QC879.8.R642 1979
The Role of temperate zone forests in the world carbon cycle problem definition and research needs.
Armentano, T. V.; Hett, J.
United States, Dept. of Energy, Office of Health and Environmental Research, Institute of Ecology Indianapolis, Ind. : Institute of Ecology (TIE); 1979.
ii, 69 leaves : ill., maps ; 28 cm. "Prepared for Dept. of Energy, Office of Environment, Office of Health and Environmental Research, Carbon Dioxide and Climate Research Program", cover. Work supported by U.S. Department of Energy, Office of Environment, under contract no. 79EV10040.000. Photocopy. "Report of a workshop, Indianapolis, Indiana, March 21-22, 1979", cover. "DOE/ET-10040-1", cover. "N80-23883", cover. Bibliography: p. 39-43.

Language: English

Descriptors: Atmospheric carbon dioxide; Forest influences

381 NAL Call No: QC988.A66G4
Role of the tropics in atmospheric chemistry.
Crutzen, P.J.
New York : John Wiley for the United Nations University; 1987.
The Geophysiology of Amazonia : vegetation and climate interactions / Robert E. Dickinson, editor. p. 107-130; 1987. Literature review. Includes references.

Language: English

Descriptors: Biomass; Ecosystems; Flora; Forest influences; Tropical forests; Vegetation; Atmospheric sciences; Gases; Carbon dioxide; Carbon monoxide; Hydrogen; Methane

382 NAL Call No: QC981.8.G56S32
Scientific perspectives on the greenhouse problem.
George C Marshall Institute
Washington, D.C. George C Marshall Institute; 1989.
i, 37 p. : ill. ; 24 cm. The George C Marshall Institute provides technical assessments of scientific developments with a major public policy impact.

Language: English

Descriptors: Greenhouse effect; Global warming; Climatic changes

383 NAL Call No: QC981.8.G56S3
Scientific perspectives on the greenhouse problem executive summary.
George C Marshall Institute
Washington, D.C. George C Marshall Institute; 1989.
13 p. : ill. ; 24 cm. Extract from the full report... The George C Marshall Institute provides technical assessments of scientific developments with a major public policy impact.

Language: English

Descriptors: Greenhouse effect; Global warming; Climatic changes

384 NAL Call No: RA565.S365
Scientific uncertainty and decision making: the case of greenhouse gases and global climate change.
Laurmann, J.A.
Amsterdam, Netherlands : Elsevier Science Publishers B.V.; 1986 Nov01.
The science of the total environment v. 55: p. 177-186; 1986 Nov01. Includes references.

Language: English

Descriptors: Greenhouses; Gases; Carbon dioxide; Climate

385 NAL Call No: 99.8 F768
Scientists studying "the greenhouse effect" challenge fears of global warming.
Wheeler, D.L.
Bethesda, Md. : Society of American Foresters; 1990 Jul.
Journal of forestry v. 88 (7): p. 34-36; 1990 Jul. Includes references.

Language: English

Descriptors: Climatic change; Temperatures; Human activity; Carbon dioxide; Computer applications

386 NAL Call No: S541.5.A4M57
Sea ice, carbon dioxide, and climate.
Weller, G.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 199-208. ill., maps; 1984 Mar. Literature review. Includes references.

Language: English

Descriptors: Antarctica; Carbon dioxide; Oceanography; Climatic change; Icebergs; Temperature relations

387 NAL Call No: 470 S12
A second look at the impacts of climate change.
Ausubel, J.H.
Research Triangle Park, N.C. : Sigma Xi, The Scientific Research Society; 1991 May.
American scientist v. 79 (3): p. 210-221; 1991 May. Includes references.

Language: English

Descriptors: Agriculture; Ecology; Climatic change

388 NAL Call No: QC981.8.C5S96 1991
Second Symposium on Global Change Studies, Jan. 14-18, 1991, New Orleans, La.
American Meteorological Society
Symposium on Global Change Studies 2nd : 1991 : New Orleans, La.
Boston, MA : American Meteorological Society; 1991.
ix, 136, [39] p. : ill. ; 28 cm. Includes bibliographical references and index.

Language: English

Descriptors: Climatic changes

389 NAL Call No: QH540.E55
Sensitivity of the arctic climate: a factor in developing planning strategies for our Arctic Heritage.
LeDrew, E.F.
Geneva : Elsevier Sequoia S.A.; 1986.
Environmental conservation v. 13 (3): p. 215-228. ill., maps; 1986. Includes references.

Language: English

Descriptors: Arctic regions; Climate; Climatic change; Development; Planning; Conservation; Ecology

390 NAL Call No: SD143.S64
Siege of 1987: 100-year occurrence or harbinger of tomorrow.
Blonski, K.S.
Bethesda, Md. : The Society; 1989.
Proceedings of the ... Society of American Foresters National Convention. p. 80-82; 1989. Meeting held Oct 16-19, 1988, Rochester, New York.

Language: English

Descriptors: California; Forest fires; Wildfires; Fire control; Planning; Population pressure; Climatic change

391 NAL Call No: QH543.P76
The significance of biospheric carbon pools and fluxes for the atmospheric CO2: a proposed model structure.
Esser, G.
Lisse : Swets & Zeitlinger; 1984.
Progress in biometeorology v. 3: p. 253-294. maps; 1984. Paper presented at the "Symposium on Interactions between Climate and Biosphere," March 21-23, 1983, Osnabruck, West Germany. Includes statistical data. Includes references.

Language: English

Descriptors: Atmosphere; Carbon dioxide; Biota; Vegetation; Source sink relations; Models

392 NAL Call No: GB395.A73
The significance of the date of snow disappearance on the arctic tundra as a possible indicator of climate change.
Foster, J.L.
Boulder, Colo. : Institute of Arctic and Alpine Research, University of Colorado; 1989 Feb.
Arctic and alpine research v. 21 (1): p. 60-70. maps; 1989 Feb. Includes references.

Language: English

Descriptors: Alaska; U.S.S.R.; Canada; Scandinavia; Snow cover; Winter; Duration; Arctic tundra; Climatic change; Albedo; Air pollution; Polar climate; Trends

393 NAL Call No: QC981.S55
Simulating climate with two different numerical schemes.
Gutowski, William J.
Carbon Dioxide Research Program (U.S.)

Washington, D.C. : The Department ; Springfield, Va. : Available from National Technical Information Service; 1990.
vii, 57 p. : ill. ; 28 cm. "C02", Cover. June 1990. TRO49. DOE/ER-0459T. Contract no. DE-FG02-86ER60422. Includes bibliographical references (p. 55-57).

Language: English

Descriptors: Climatology; Climatic changes; Atmospheric circulation

394 **NAL Call No: SD390.7.G73G74**
Simulating forest ecosystem responses to expected climate change in eastern climate change in eastern North America: applications to decision making in the forest industry.
Solomon, A.M.; West, D.C.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 189-217; 1987. Literature review. Includes references.

Language: English

Descriptors: Ontario; Michigan; North eastern states of U.S.A.; South eastern states of U.S.A.; Forest trees; Forest ecology; Growth rate; Climatic change; Carbon dioxide; Simulation; Models; Decision making

395 **NAL Call No: FICHE S-72**
Simulation as a tool for analyzing crop response to climate change.
Curry, R.B.; Jones, J.W.; Boote, K.J.; Allen, L.H. Jr
St. Joseph, Mich. : The Society; 1988.
American Society of Agricultural Engineers (Microfiche collection) (fiche no. 88-7512): 30 p. maps; 1988. Paper presented at the 1988 Winter Meeting of the American Society of Agricultural Engineers. Available for purchase from: The American Society of Agricultural Engineers, Order Dept., 2950 Niles Road, St. Joseph, Michigan 49085. Telephone the Order Dept. at (616) 429-0300 for information and prices. Includes references.

Language: English

Descriptors: Zea mays; Glycine max; Weather data; Atmosphere; Carbon dioxide; Yield response functions; Simulation models

396 **NAL Call No: 290.9 AM32T**
Simulation as a tool for analyzing crop response to climate change.
Curry, R.B.; Peart, R.M.; Jones, J.W.; Boote, K.J.; Allen, L.H. Jr
St. Joseph, Mich. : American Society of Agricultural Engineers; 1990 May.
Transactions of the ASAE v. 33 (3): p. 981-990. maps; 1990 May. Includes references.

Language: English

Descriptors: Glycine max; Zea mays; Growth; Weather; Simulation models; Irrigation; Carbon dioxide

397 **NAL Call No: 472 N21**
Simulation of the regional climatic impact of Amazon deforestation.
Lean, J.; Warrilow, D.A.
London : Macmillan Magazines Ltd; 1989 Nov23.
Nature v. 342 (6248): p. 411-413. maps; 1989 Nov23. Includes references.

Language: English

Descriptors: South America; Deforestation; Erosion; Climatic change; Simulation models; Tropical rain forests

Abstract: The Amazon basin contains about half of Earth's Tropical forest. Population pressure and subsequent demands for crop production, timber and firewood have led to rapid deforestation. Quantitative estimates of the rate of deforestation from analysis of Landsat observations indicate that rates are increasing exponentially in many regions, but the precise figures are not known. Removal of the protection provided by natural cover can lead to soil erosion, disturbance of the ecosystem and reduction in species diversity. Here we report results from a three-year simulation, using a general circulation model, in which we replace Amazon tropical forest and savannah with pasture. The simulated local climate response was dominated by a weakened hydrological cycle, with less precipitation and evaporation and an increase in surface temperature. The reductions in precipitation and evaporation were mostly caused by changes in surface roughness and albedo: decreased roughness dominated the reduction in evaporation (and the increase in temperature), whereas the increased albedo was the main cause of a decrease in the moisture flux convergence (measured as the difference between precipitation and evaporation) contributing to the decrease in precipitation.

398 NAL Call No: TD420.A1E5
Slowing global warming.
Flavin, C.
Washington, D.C. : American Chemical Society; 1990 Feb.
Environmental science & technology v. 24 (2): p. 170-171. ill; 1990 Feb. Includes references.

Language: English

Descriptors: Air pollution; Air pollutants; Temperature inversion; Carbon dioxide; Forest influences; Climatic change

399 NAL Call No: 99.8 F762
Slowing global warming.
Flavin, C.
Washington, D.C. : American Forestry Association; 1990 Jun.
American forests v. 96 (5/6): p. 37-44; 1990 Jun.

Language: English

Descriptors: Climatic change; Temperatures; Air pollution; Environmental pollution; Fossil fuels; Emission; Deforestation

400 NAL Call No: QC981.8.G56F52
Slowing global warming a worldwide strategy.
Flavin, Christopher
Worldwatch Institute
Washington, D.C., USA : Worldwatch Institute; 1989.
94 p. : ill. ; 22 cm. (Worldwatch paper ; 91). October 1989. Bibliography: p. 75-94.

Language: English

Descriptors: Global warming; Climatic changes; Greenhouse effect, Atmospheric

401 NAL Call No: QC981.8.C5S634
Societal responses to regional climatic change forecasting by analogy.
Glantz, Michael H.
Boulder, Colo. : Westview Press; 1988.
428 p. : ill. ; 23 cm. Includes bibliographies.

Language: English

Descriptors: Climatic changes; Social aspects; North America; Environmental impact analysis; North America

402 NAL Call No: QK867.J67
Soil organic matter and the global carbon cycle.
Wallace, A.; Wallace, G.A.; Cha, J.W.
New York, N.Y. : Marcel Dekker; 1990.
Journal of plant nutrition v. 13 (3/4): p. 459-466; 1990. Paper published in "Interactions of Limiting Factors in Crop Production", a special issue devoted to research papers by Dr. Arthur Wallace. Includes references.

Language: English

Descriptors: Organic matter in soil; Carbon cycle; Soil amendments; Organic fertilizers; Microbial degradation; Soil flora; Nitrogen; Nutrient availability; Limiting factors; Nitrogen fixation; Carbon dioxide; Atmosphere; Air temperature; Climatic change

403 NAL Call No: S596.3.I58 1989
Soils and the greenhouse effect the present status and future trends concerning the effect of soils and their cover on the fluxes of greenhouse gasses, the surface energy balance, and the water balance : proceedings of the International Conference Soils and the Greenhouse Effect.
Bouwman, A. F.
International Soil Reference and Information Centre, Netherlands, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Commission of the European Communities, United Nations Environment Programme
International Conference Soils and the Greenhouse Effect 1989 : Wageningen, Netherlands.
Chichester ; New York : Wiley; 1990.
xviii, 575 p. : ill. ; 24 cm. Sponsored by the Commission of the European Communities (CEC), the United Nations Environment Programme (UNEP). Conference held Aug. 14-18, 1989, Wageningen, Netherlands. Includes bibliographical references and index.

Language: English

Descriptors: Soils and climate; Congresses; Greenhouse effect, Atmospheric; Congresses; Soil ecology; Congresses

404 NAL Call No: S541.5.A4M57
Some aspects of vegetation and temperature relationships in the Alaska taiga.
Viereck, L.A.; Van Cleve, K.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 129-142. ill; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Taiga; Weather data; Climatic

change; Forest succession; Treelines and timberlines; Carbon dioxide; Nutrient cycles; Vegetation

405 NAL Call No: aQK751.U7 1988
Spatial patterns of climatic response for eastern hemlock and the potential impact of future climatic change.
Cook, E.R.; Cole, J.
Broomall, PA : Northeastern Forest Experiment Station, [1989?]; 1989 Sep.
Air pollution effects on vegetation, including forest ecosystems : proceedings of the Second US-USSR Symposium / edited by Reginald D. Noble, Juri L. Martin, and Keith F. Jensen. p. 27-36. maps; 1989 Sep. Papers presented at an International Conference, September 13-25, 1988, at Corvallis, Oregon; Raleigh, North Carolina; Gatlinburg, Tennessee. Includes references.

Language: English

Descriptors: Tsuga canadensis; Climatic change; Responses

406 NAL Call No: QC988.A66G4
Species diversity, phenology, plant-animal interactions, and their correlation with climate, as illustrated by the Brazil nut family (Lecythidaceae).
Mori, S.A.; Prance, G.T.
New York : John Wiley for the United Nations University; 1987.
The Geophysiology of Amazonia : vegetation and climate interactions / Robert E. Dickinson, editor. p. 69-89. ill; 1987. Includes references.

Language: English

Descriptors: Brazil; Lecythidaceae; Forest ecology; Phenology; Plants; Animals; Tropical forests; Interactions; Pollination; Seed dispersal; Climatic change

407 NAL Call No: S541.5.A4M57
Spring snow dissipation in Alaska.
Robinson, D.A.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 124-128. maps; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Carbon dioxide; Snow cover; Albedo; Climatic change; Projections; Spring

408 NAL Call No: QC881.2.S8U54
Stratospheric ozone 1988 second report.
United Kingdom Stratospheric Ozone Review Group; Great Britain, Dept. of the Environment, Great Britain, Meteorological Office
London : H.M.S.O.; 1988.
71 p. : ill. ; 30 cm. Prepared at the request of the Department of the Environment and the Meteorological Office. "September 1988", Cover. Includes bibliographical referencces (p. 57-60).

Language: English

Descriptors: Ozone layer; Atmospheric ozone; Stratosphere; Ozone layer depletion

409 NAL Call No: KF26.E645 1987e
Stratospheric ozone depletion and chlorofluorocarbons joint hearings before the Subcommittees on Environmental Protection and Hazardous Wastes and Toxic Substances of the Committee on Environment and Public Works, United States Senate, One hundredth Congress, first session ... May 12, 13, and 14, 1987.
United States. Congress. Senate. Committee on Environment and Public Works. Subcommittee on Environmental Protection; United States, Congress, Senate, Committee on Environment and Public Works, Subcommittee on Hazardous Wastes and Toxic Substances
Washington, [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1987; Y 4.P 96/10-S.hrg.100-201.
v, 677 p. : ill., 1 map ; 24 cm. (S. hrg. ; 100-201). Distributed to some depository libraries in microfiche. Includes bibliographies.

Language: English

Descriptors: Stratosphere, United States; Chlorofluorocarbons; Ozone

410 NAL Call No: QC881.2.O9U54
Stratospheric ozone EPA's safety assessment of substitutes for ozone-depleting chemicals : report to the chairman, Committee on Energy and Commerce, House of Representatives. (EPA's safety assessment of substitutes for ozone-depleting chemicals.)
United States. General Accounting Office
Washington, D.C. : The Office; 1989.
66 p. : ill. ; 28 cm. Cover title. February 1989. GAO/RCED-89-49. "B-232917", P. [1]. Includes bibliographical references.

Language: English

Descriptors: Ozone layer; Ozone layer depletion;

Chlorofluorocarbons; Bromotrifluoromethane

411 NAL Call No: QC881.2.S8U5
Stratospheric ozone first report.
United Kingdom Stratospheric Ozone Review Group; Great Britain, Dept. of the Environment, Great Britain, Meteorological Office
London : H.M.S.O. : Available from HMSO Publications Centre; 1987.
83 p., [3] p. of plates : ill. (some col.) ; 30 cm. Prepared at the request of the Department of the Environment and the Meteorological Office. Bibliography: p. 77-78.

Language: English

Descriptors: Ozone layer

412 NAL Call No: 500 AS73
Summer circulation climate of the American Southwest, 1945-1984.
Carleton, A.M.
Washington, D.C. : The Association; 1987 Dec.
Annals of the Association of American Geographers v. 77 (4): p. 619-634. maps; 1987 Dec. Includes references.

Language: English

Descriptors: U.S.A.; Climatology; Classification; Climatic change; Summer; Prediction

413 NAL Call No: 80 AM371
Summer droughts and the "greenhouse effect".
Cosgrove, T.
Chicago, Ill. : American Nurseryman Publishing Company; 1988 Nov15.
American nurseryman v. 168 (10): p. 23-26, 28-30, 32-33; 1988 Nov15.

Language: English

Descriptors: Drought; Summer; Air pollutants; Weather patterns; Heat; Temperatures; Climatology; Models

414 NAL Call No: Q184.R4
Surface albedo from bidirectional reflectance.
Ranson, K.J.; Irons, J.R.; Daughtry, C.S.T.
New York, N.Y. : Elsevier Science Publishing; 1991 Feb.
Remote sensing of environment v. 35 (2/3): p. 201-211; 1991 Feb. Paper presented at the "Symposium on Remote Sensing for Agriculture," May 16-18, 1990, Beltsville, Maryland. Includes references.

Language: English

Descriptors: Albedo; Land; Surfaces; Climatology; Climatic change; Remote sensing; Spectral data; Radiometers; Pyranometers; Vegetation; Soil

415 NAL Call No: KF27.S3978 1988l
Technologies for remediating global warming hearing before the Subcommittee on Natural Resources, Agriculture Research and Environment and the Subcommittee on Science, Research and Technology of the Committee on Science, Space, and Technology, U.S. House of Representatives, One Hundredth Congress, second session, June 29, 1988.
United States. Congress. House. Committee on Science, Space, and Technology. Subcommittee on Natural Resources, Agriculture Research, and Environment; United States, Congress, House, Committee on Science, Space, and Technology, Subcommittee on Science, Research, and Technology
Washington [D.C.] : U.S. G.P.O. : For sale by the Supt. of Docs., Congressional Sales Office, U.S. G.P.O.; 1988; Y 4.Sci 2:100/137.
iii, 245 p. : ill. ; 24 cm. Distributed to some depository libraries in microfiche. No. 137. Includes bibliographies.

Language: English

Descriptors: Greenhouse effect, Atmospheric, Technological innovations; Air, Pollution, Meteorological aspects; Environmental policy, United States

416 NAL Call No: QC981.8.C5T4
Teleconnections linking worldwide climate anomalies scientific basis and societal impact.
Glantz, Michael H.; Katz, Richard W.; Nicholls, N.
Cambridge [England] ; New York : Cambridge University Press; 1991.
x, 535 p. : ill., maps ; 26 cm. Includes bibliographical references and index.

Language: English

Descriptors: El Nino Current; Climatic changes; Southern oscillation

417 NAL Call No: S541.5.A4M57
Temperature trends in the Alaska climate record: problems, update, and prospects.
Juday, G.P.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-1): p. 76-91; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Temperature; Summer; Winter; Seasonal fluctuations; Cyclic fluctuations; Projections; Climatic change

418 NAL Call No: SD143.S64
Threats to a healthy forest by air pollution and climate change.
Addison, P.A.
Bethesda, Md. : The Society; 1989.
Proceedings of the ... Society of American Foresters National Convention. p. 21-26; 1989. Meeting held Oct 16-19, 1988, Rochester, New York. Includes references.

Language: English

Descriptors: Forests; Air pollution; Climatic change; Forest damage; Human activity; Emission

419 NAL Call No: SD390.7.G73G74
Time to prepare for global climatic change.
Roberts, W.O.
Washington, D.C. : Conservation Foundation; 1987.
The Greenhouse effect, climate change, and U.S. forests / edited by William E. Shands and John S. Hoffman. p. 9-17; 1987. Includes references.

Language: English

Descriptors: Climatic change; Carbon dioxide; Weather; Thermal radiation; World problems

420 NAL Call No: QL750.O3
Transient response of forests to CO2-induced climate change: simulation modeling experiments in eastern North America.
Solomon, A.M.
Berlin, W. Ger. : Springer International; 1986.
Oecologia v. 68 (4): p. 567-579. ill., maps; 1986. Includes references.

Language: English

Descriptors: North America; Forests; Climatic change; Carbon dioxide; Simulation models; Stress response

421 NAL Call No: 340.8 AG8
Turbulence spectra of CO2, water vapor, temperature and velocity over a deciduous forest.
Anderson, D.E.; Verma, S.B.; Clement, R.J.; Baldocchi, D.D.; Matt, D.R.
Amsterdam : Elsevier Science Publishers; 1986 Oct.
Agricultural and forest meteorology v. 38 (1/3): p. 81-99. maps; 1986 Oct. Includes references.

Language: English

Descriptors: Deciduous seasonal forests; Carbon dioxide; Water vapor; Air temperature; Velocity; Turbulent flow

422 NAL Call No: NbUS600.T8A53 1983
Turbulent exchange of carbon dioxide, water vapor, heat and momentum over crop surfaces.
Anderson, Dean E.
Lincoln : Center for Agricultural Meteorology and Climatology, University of Nebraska-Lincoln; 1983.
186 p. : ill. ; 28 cm. (Progress report (University of Nebraska, Lincoln. Center for Agricultural Meteorology and Climatology) ; 83-8.). Originally published as the author's thesis. Bibliography: p. 170-181.

Language: English

Descriptors: Plants, Effect of turbulence on; Atmospheric turbulence; Soybean, Field experiments; Sorghum, Field experiments; Meteorology, Agricultural

423 NAL Call No: QC981.8.C5P4
Turning up the heat our perilous future in the global greenhouse.
Pearce, Fred
London, [England] : Bodley Head; 1989.
229 p. : ill. ; 22 cm.

Language: English

Descriptors: Climatic changes; Man; Influence on nature

424 NAL Call No: SD13.C35
Twentieth-century climate change, fire suppression, and forest production and decomposition in northwestern Minnesota.
Clark, J.S.
Ottawa, Ont. : National Research Council of Canada; 1990 Feb.
Canadian journal of forest research; Journal canadien de recherche forestiere v. 20 (2): p. 219-232; 1990 Feb. Includes references.

Language: English

Descriptors: Minnesota; Forest fires; Climatic factors; History; Fire suppression; Fuel accumulation;

Biomass accumulation; Mixed forests; Coniferous forest; Simulation models

425 NAL Call No: QC981.8.C5U48
Understanding climate change.
Berger, A.1942-; Dickinson, Robert E.1940-; Kidson, J.
Washington, D.C. : American Geophysical Union : International Union of Geodesy and Geophysics; 1989.
xi, 187 p. : ill. ; 28 cm. (Geophysical monograph/IUGG series ; 7 Geophysical monograph ; 52). Includes bibliographical references.

Language: English

Descriptors: Climatic changes; Congresses

426 NAL Call No: 275.29 G29B
Understanding global changes: the greenhouse effect.
Coder, K.D.
Athens, Ga. : The Service; 1991 Mar.
Bulletin - Cooperative Extension Service, University of Georgia, College of Agriculture (1046): 8 p. ill; 1991 Mar.

Language: English

Descriptors: Environmental temperature; Solar heating; Carbon dioxide

427 NAL Call No: SD143.S64
Urban forestry, carbon dioxide and global climate change.
Rowntree, R.A.
Bethesda, Md. : The Society; 1990.
Proceedings of the ... Society of American Foresters National Convention. p. 429-433; 1990. Paper presented at a meeting on "Forestry on the Frontier," Sept 24-27, 1989, Spokane, Washington. Includes references.

Language: English

Descriptors: Urban forestry; Climatic change; Carbon dioxide; Deforestation; Environmental degradation

428 NAL Call No: QC981.8.C5N37
The U.S. global change research program an assessment of FY 1991 plans. (Global change research program.)
National Research Council (U.S.)
Washington, D.C. : National Academy Press; 1990.
xvi, 107 p. : ill. ; 23 cm. Bibliography: p. 103-[104].

Language: English

Descriptors: Climatic changes; Earth; Geodynamics

429 NAL Call No: HM208.E5
The use of analogies in forecasting ecological and societal responses in global warming.
Glantz, M.H.
Washington, D.C. : Heldref Publications; 1991 Jun.
Environment v. 33 (5): p. 10-15, 27-33; 1991 Jun. Includes references.

Language: English

Descriptors: Climatic change; Precipitation; Soil water; Comparisons

430 NAL Call No: QH540.N3
UV-B radiation and adaptive mechanisms in plants.
Beggs, C.J.; Schneider-Ziebert, U.; Wellmann, E.
Berlin, W. Ger. : Springer-Verlag; 1986.
N.A.T.O. A.S.I (Advanced Study Institute) series. Series G. Ecological sciences v. 8: p. 236-250; 1986. Paper presented at the "Workshop on The Impact of Solar Ultraviolet Radiation upon Terrestial Ecosystems: 1. Agricultural Crops," Sept 27-30, 1983, Windsheim, West Germany. Literature review. Includes references.

Language: English

Descriptors: Ultraviolet radiation; Adaptation; Leaves; Cotyledons; Phaseolus vulgaris; Pigments; Plant damage; Dna; Solar radiation; Radiation protection

431 NAL Call No: 500 IO93
Variability of annual Iowa precipitation during the past 95 years.
Vaughan, H.C.; Berning, D.J.; White, G.R.
Cedar Falls, Iowa : The Academy; 1987 Sep.
The Proceedings of the Iowa Academy of Science v. 94 (3): p. 94-104; 1987 Sep. Includes references.

Language: English

Descriptors: Iowa; Precipitation; Climate; Climatic change

432 NAL Call No: S541.5.A4M57
The variability of the present climate of interior Alaska.
Bowling, S.A.
Fairbanks, Alaska : The Station; 1984 Mar.
Miscellaneous publication - University of Alaska, Agricultural and Forestry Experiment Station (83-

1): p. 67-75; 1984 Mar. Includes references.

Language: English

Descriptors: Alaska; Carbon dioxide; Weather data; Climatic change; Seasonal fluctuations

433 NAL Call No: 56.8 C162
Weather sensitivity of western Canada wheat yield, 1900-1988.
Walker, G.K.
Ottawa : Agricultural Institute of Canada; 1989 Nov.
Canadian journal of soil science v. 69 (4): p. 857-865; 1989 Nov. Includes refcrences.

Language: English

Descriptors: Saskatchewan; Triticum aestivum; Crop yicld; Climatic change; Weather data; Simulation models

434 NAL Call No: S592.17.A73S46
Weather-predictive models.
Hargreaves, G.H.; Samani, Z.A.
New York, N.Y. : M. Dekker; 1991.
Semiarid lands and deserts : soil resource and reclamation / edited by J. Skujins. p. 581-603; 1991. (Books in soils, plants, and the environment :). Includes references.

Language: English

Descriptors: Arid climate; Semiarid climate; Weather; Models; Crop production; Crop yield; Agricultural planning; Climatic change; Prediction

435 NAL Call No: QC983.W435
Weekly climate bulletin.
Climate Analysis Center (U.S.)
Washington, DC : Climate Analysis Center, NMC, National Weather Service, NOAA; 19??-9999.
v. : maps ; 28 cm. Description based on: No. 88/25 (June 18, 1988); title from cover.

Language: English

Descriptors: Weather; Periodicals; Climatic changes; Periodicals; Climatology; Periodicals; United States; Climate; Periodicals

436 NAL Call No: 500 N483J
Where's the heat?
Washington, W.M.
New York, N.Y. : American Museum of Natural History; 1990 Mar.
Natural history (3): p. 67-68, 70. ill., maps; 1990 Mar.

Language: English

Descriptors: Air temperature; Carbon dioxide; Climatology; Circulation; Oceanography

437 NAL Call No: QK710.T4 no.32
Will climatic change provide new challenges for plant physiologists?
PPD Climate Change Collective
Palmerston North, [N.Z.?] : Plant Physiology Division, Dept. of Scientific and Industrial Research, [1989?]; 1989.
6, [6] leaves : ill. ; 30 cm. (Technical report / Plant Physiology Division, Dept. of Scientific and Industrial Research, no. 32). August 1989. Includes bibliographical references (leaf 6).

Language: English

438 NAL Call No: QH540.A52
Will climatic changes flood the Netherlands? Effects on agriculture, land use and well-being.
Hekstra, G.P.
Stockholm : Royal Swedish Academy of Sciences; 1986.
Ambio v. 15 (6): p. 316-326. ill., maps; 1986. Includes 12 references.

Language: English

Descriptors: Netherlands; Climatic change; Carbon dioxide; Floods; Agriculture; Land use; Air pollution

439 NAL Call No: QC981.8.C5
Winds of change living in the global greenhouse.
Gribbin, John; Kelly, Mick,
Kent? : Hodder & Stoughton; 1989.
162 p. : col. ill., maps ; 22 cm. Headway. "This publication accompanies the television documentary "can polar bears tread water?" produced by Central Independant Television plc in association with Television for the Environment and the Better World Society", T.p. verso.

Language: English

Descriptors: Climatic changes

440 NAL Call No: 101 AL1A
Winters are getting drier: and its matters especially to farmers.
McNaughton, N.
Edmonton : Faculty of Agriculture and Forestry, University of Alberta; 1989.

Agriculture and forestry bulletin v. 12 (1): p. 6-8; 1989.

Language: English

Descriptors: Alberta; Climatic change; Winter; Dry conditions; Forecasts

441 NAL Call No: QC983.W67
World climate change report.
BNA International Inc
London, England : BNA International Inc.; 1989-1990.
World climate change report. v. : ill. ; 30 cm; 1989-1990. Description based on: Vol. 1, no. 8 (June 1990); title from caption.

Language: English

Descriptors: Climactic changes; Climatology; Environmental policy

442 NAL Call No: QC981.8.C5W6
World-wide weather. (Seikai no kisho. World wide weather.)
Takahashi, Koichiro,
Rotterdam : A.A. Balkema; 1986.
xv, 252 p. : ill., maps ; 25 cm. Translation of: Seikai no kisho. Originally published: Mainichi Shimbunsha, Tokyo, 1975. Includes bibliographical references (p. [250]-252).

Language: English

Descriptors: Climatic changes; Climatology; Solar radiation

Author Index

Author Index

Author Index

Author Index

Subject Index

Subject Index

Subject Index

Subject Index

Subject Index

This publication was printed at the **UNICOR** Print Plant,
Federal Medical Center, Lexington, Kentucky